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**Sakurai et al.**

(10) **Patent No.: US 9,296,471 B2**
(45) **Date of Patent: Mar. 29, 2016**

(54) **SWING WING TIP SYSTEM, ASSEMBLY AND METHOD WITH DUAL LOAD PATH STRUCTURE**

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(73) Assignee: **The Boeing Company**, Chicago, IL (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 181 days.

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(51) **Int. Cl.**

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|---|---|
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| ***B64C 3/40*** | (2006.01) |
| ***B64C 3/56*** | (2006.01) |
| ***B64C 5/14*** | (2006.01) |
| ***B64C 23/06*** | (2006.01) |

(52) **U.S. Cl.**

CPC ... ***B64C 9/00*** (2013.01); ***B64C 3/40*** (2013.01); ***B64C 3/56*** (2013.01); ***B64C 5/14*** (2013.01); ***B64C 23/065*** (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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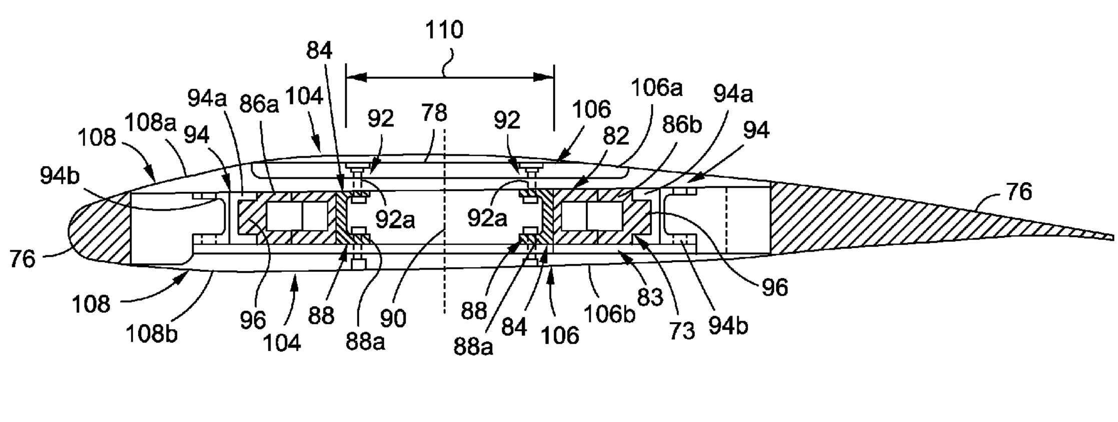
*Primary Examiner* — Medhat Badawi

(57) **ABSTRACT**

A swing wing tip system for an air vehicle is provided. The swing wing tip system has a swing wing tip assembly with an unfixed wing tip portion movably connected to a fixed wing portion of a wing. The swing wing tip assembly has a dual load path structure configured to transfer load from the unfixed wing tip portion to the fixed wing portion. The dual load path structure has dual wing skin plates and a rotation joint coupled between the dual wing skin plates and configured to rotationally couple the unfixed wing tip portion to the fixed wing portion. The rotation joint has a dual rotation pin element having a center rotation axis and dual rotation elements configured to rotate about the center rotation axis. The swing wing tip system has an actuator assembly coupled to the rotation joint and a controller system coupled to the actuator assembly.

**21 Claims, 21 Drawing Sheets**



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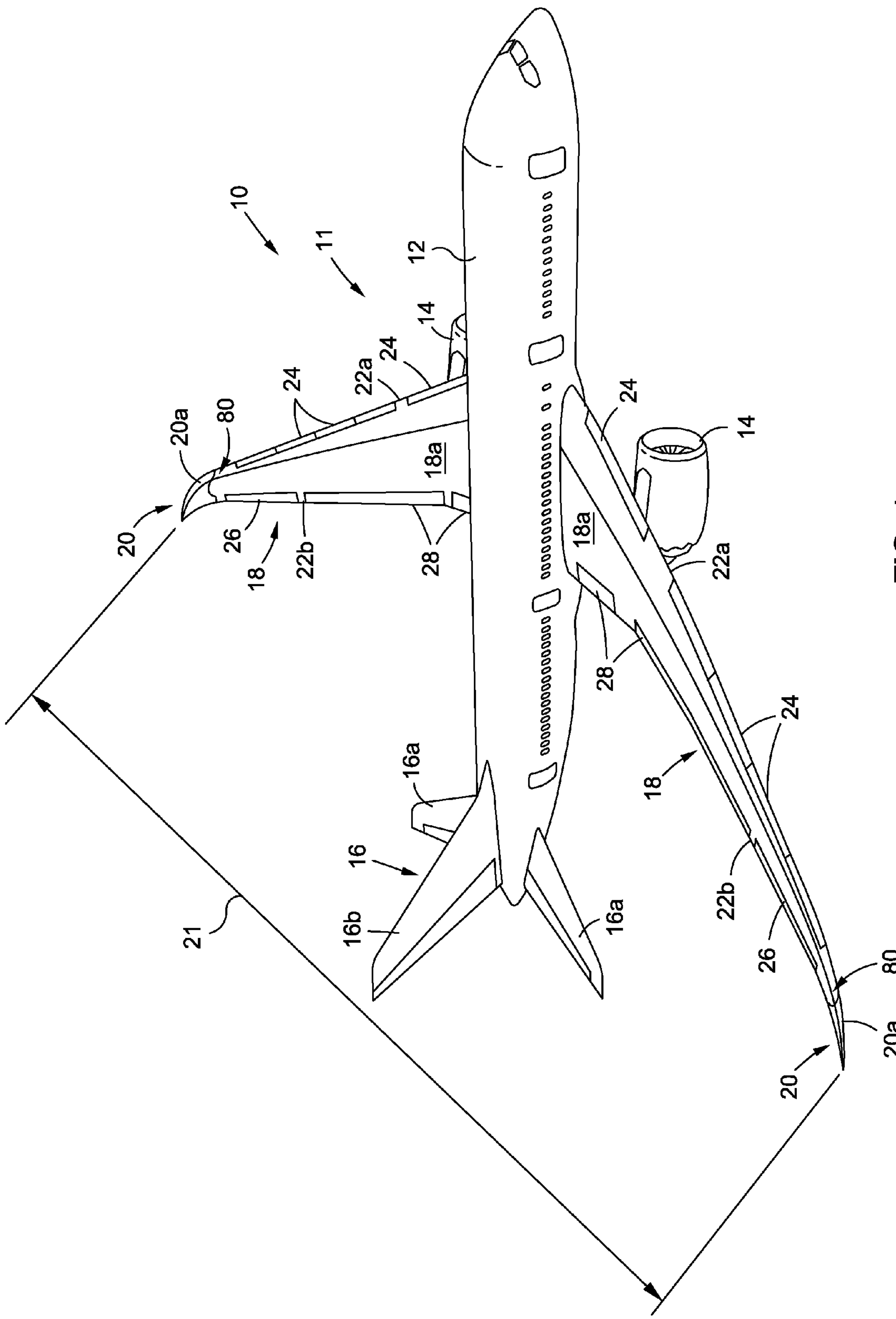
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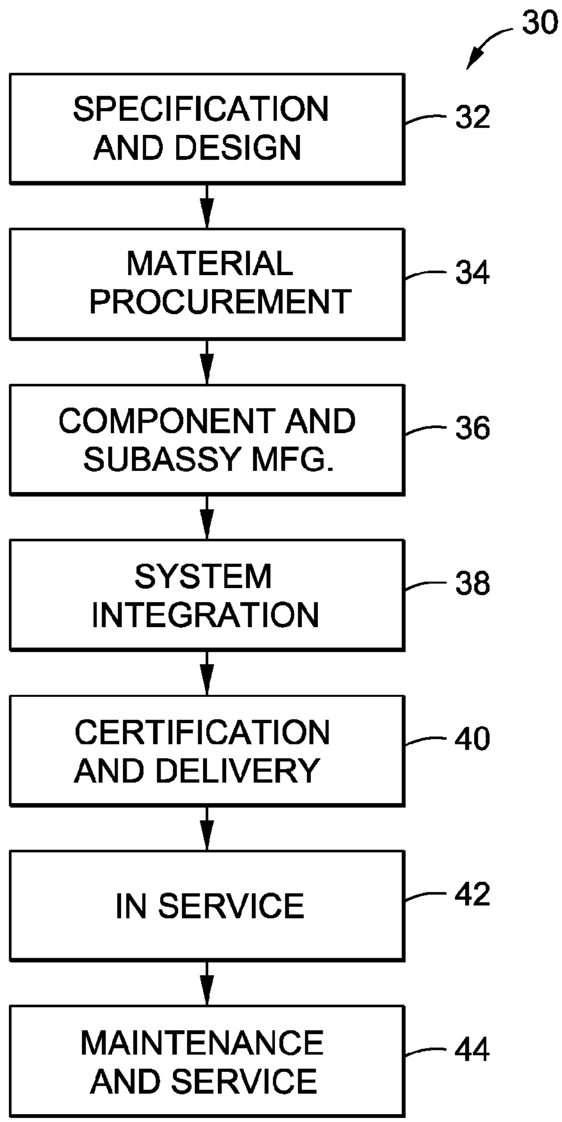
FIG. 1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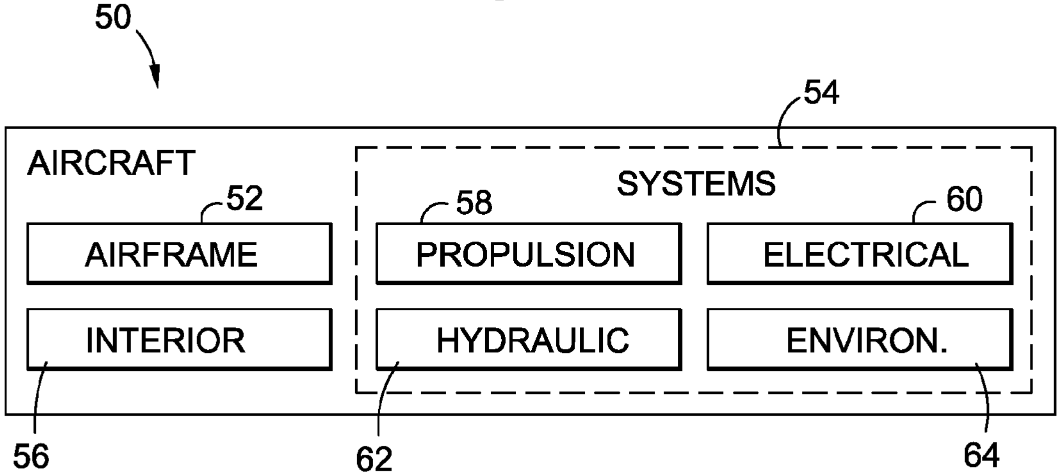
SPECIFICATION AND DESIGN
32
MATERIAL PROCUREMENT
34
COMPONENT AND SUBASSY MFG.
36
SYSTEM INTEGRATION
38
CERTIFICATION AND DELIVERY
40
IN SERVICE
42
MAINTENANCE AND SERVICE
44

FIG. 2A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54
AIRCRAFT
SYSTEMS
52
58
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AIRFRAME
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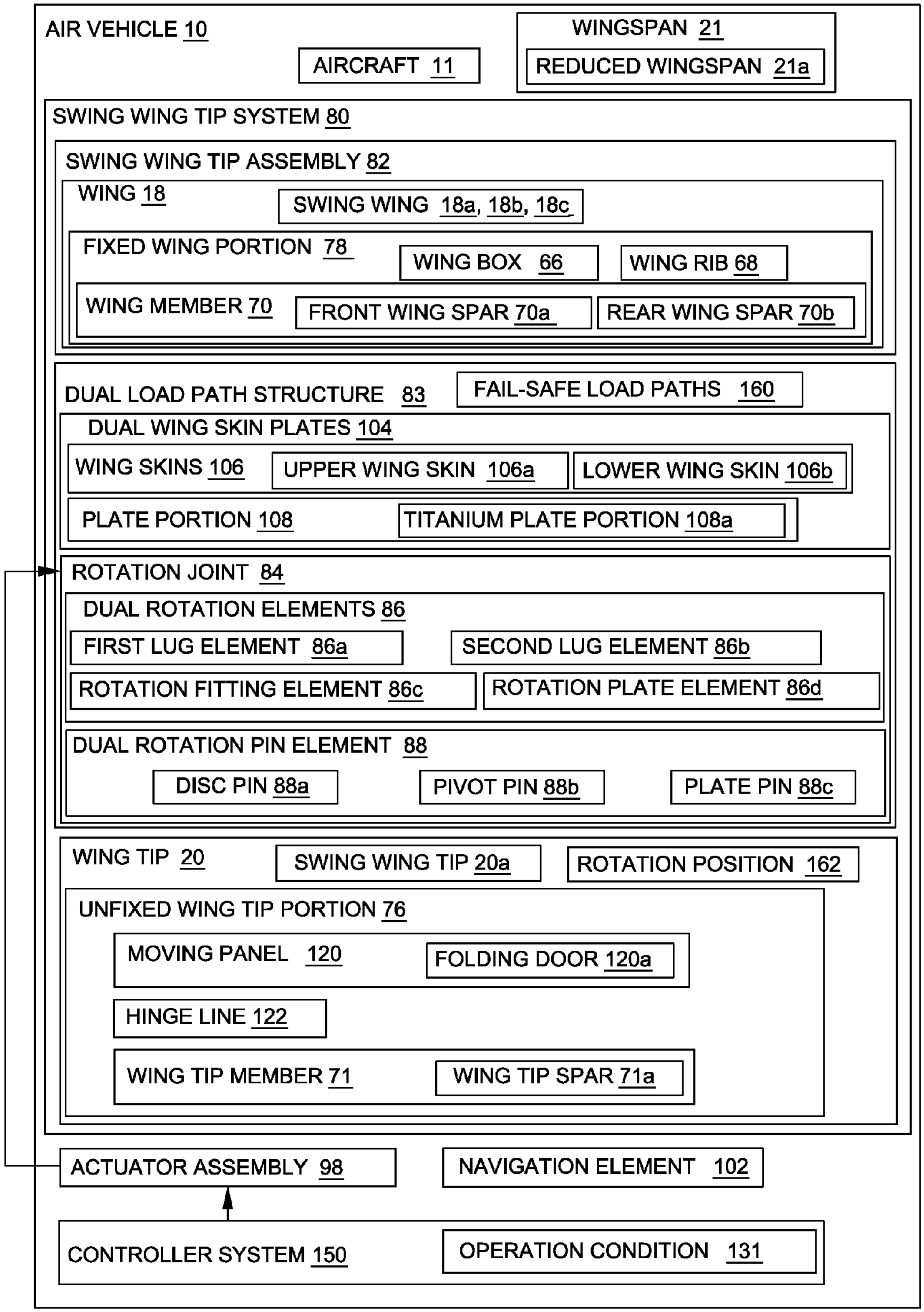
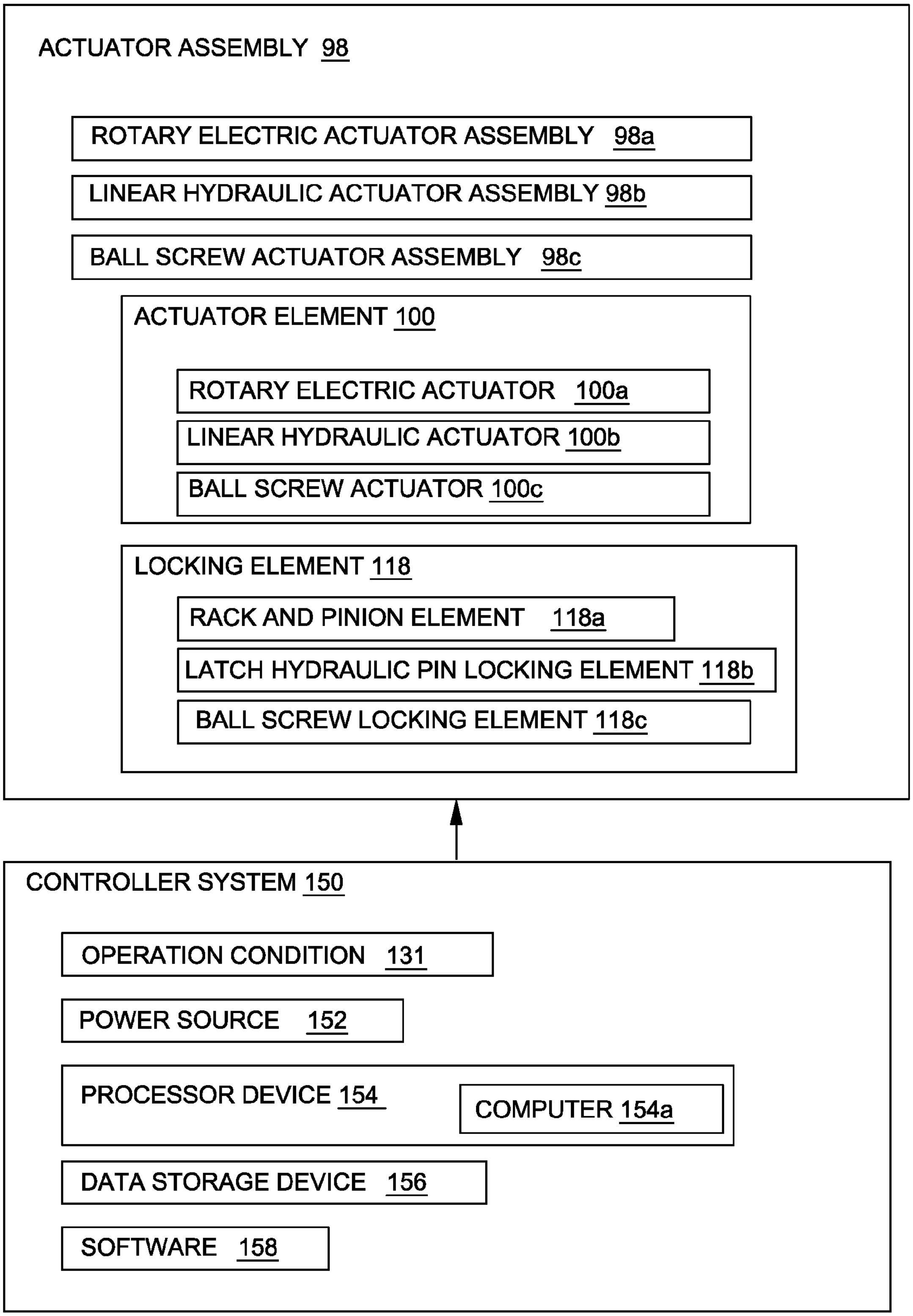
ELECTRICAL
INTERIOR
HYDRAULIC
ENVIRON.
56
62
64

FIG. 2B



AIR VEHICLE 10
AIRCRAFT 11
WINGSPAN 21
REDUCED WINGSPAN 21a
SWING WING TIP SYSTEM 80
SWING WING TIP ASSEMBLY 82
WING 18
SWING WING 18a, 18b, 18c
FIXED WING PORTION 78
WING BOX 66
WING RIB 68
WING MEMBER 70
FRONT WING SPAR 70a
REAR WING SPAR 70b
DUAL LOAD PATH STRUCTURE 83
FAIL-SAFE LOAD PATHS 160
DUAL WING SKIN PLATES 104
WING SKINS 106
UPPER WING SKIN 106a
LOWER WING SKIN 106b
PLATE PORTION 108
TITANIUM PLATE PORTION 108a
ROTATION JOINT 84
DUAL ROTATION ELEMENTS 86
FIRST LUG ELEMENT 86a
SECOND LUG ELEMENT 86b
ROTATION FITTING ELEMENT 86c
ROTATION PLATE ELEMENT 86d
DUAL ROTATION PIN ELEMENT 88
DISC PIN 88a
PIVOT PIN 88b
PLATE PIN 88c
WING TIP 20
SWING WING TIP 20a
ROTATION POSITION 162
UNFIXED WING TIP PORTION 76
MOVING PANEL 120
FOLDING DOOR 120a
HINGE LINE 122
WING TIP MEMBER 71
WING TIP SPAR 71a
ACTUATOR ASSEMBLY 98
NAVIGATION ELEMENT 102
CONTROLLER SYSTEM 150
OPERATION CONDITION 131


FIG. 3A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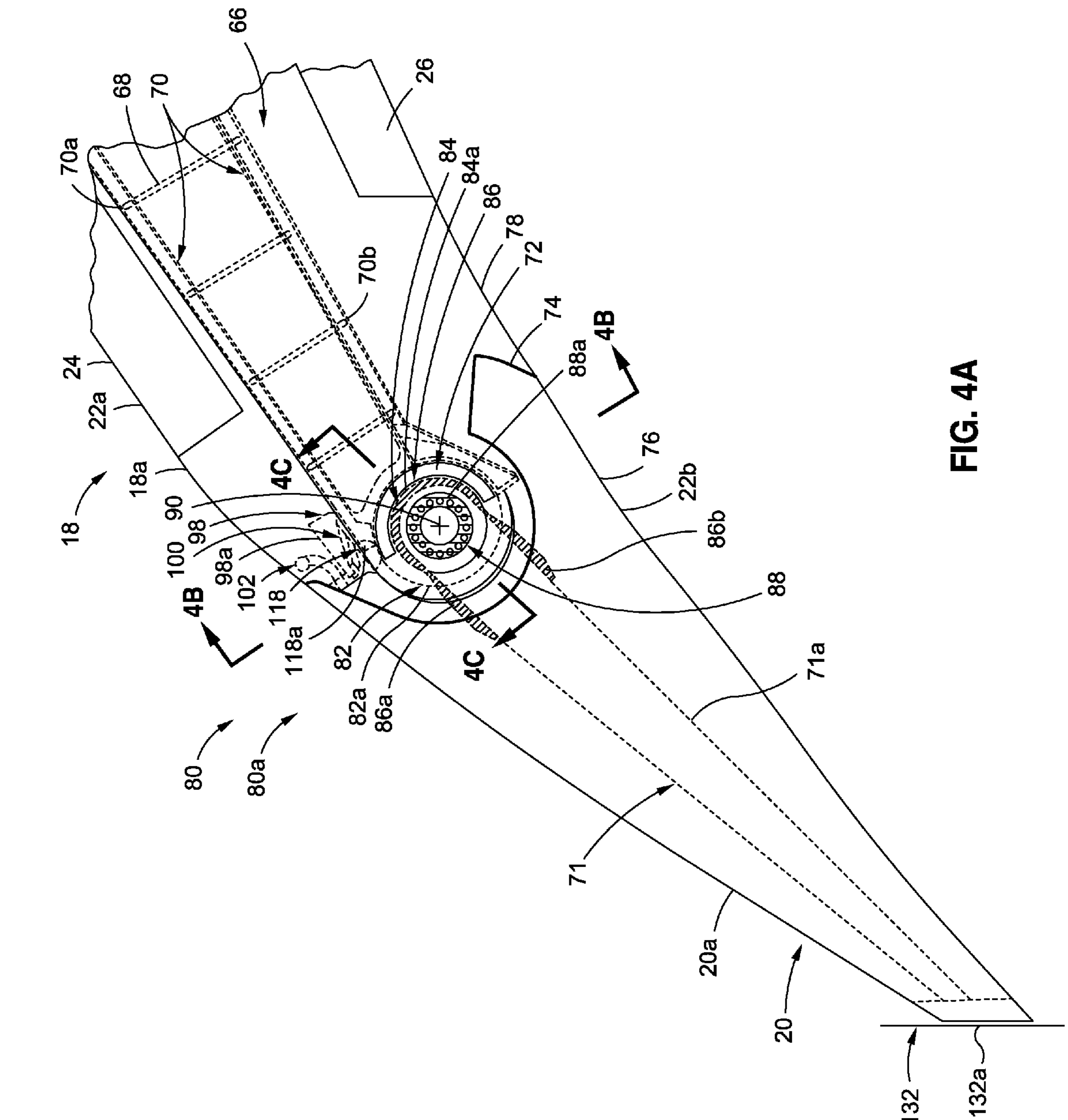
ROTARY ELECTRIC ACTUATOR ASSEMBLY 98a
LINEAR HYDRAULIC ACTUATOR ASSEMBLY 98b
BALL SCREW ACTUATOR ASSEMBLY 98c
ACTUATOR ELEMENT 100
ROTARY ELECTRIC ACTUATOR 100a
LINEAR HYDRAULIC ACTUATOR 100b
BALL SCREW ACTUATOR 100c
LOCKING ELEMENT 118
RACK AND PINION ELEMENT 118a
LATCH HYDRAULIC PIN LOCKING ELEMENT 118b
BALL SCREW LOCKING ELEMENT 118c
CONTROLLER SYSTEM 150
OPERATION CONDITION 131
POWER SOURCE 152
PROCESSOR DEVICE 154
COMPUTER 154a
DATA STORAGE DEVICE 156
SOFTWARE 158

FIG. 3B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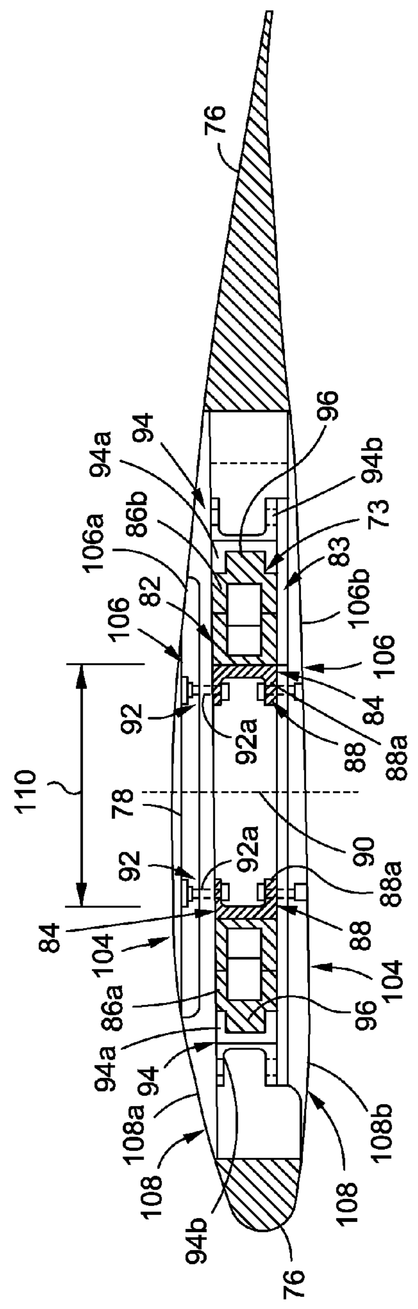
18a
18
4C
90
98
100
98a
102
118
118a
4B
82
82a
86a
4C
76
22b
86b
88
71a
80
80a
71
20a
20
132
132a

FIG. 4A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94
94a
96
94b
73
83
106a
86b
82
106
106b
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92
92a
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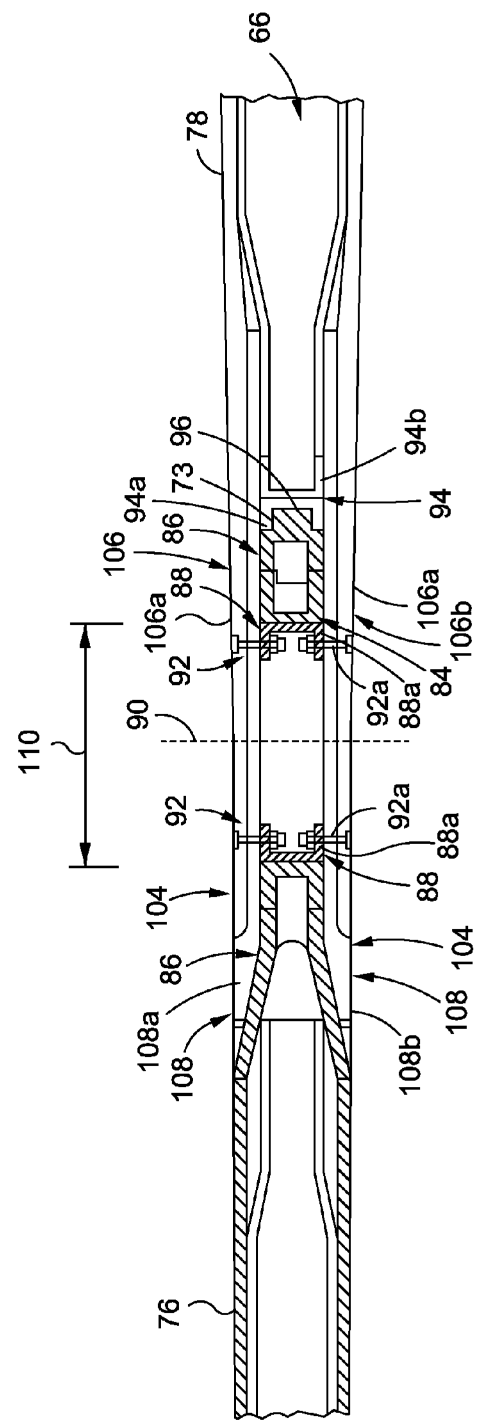
88
88a
78
90
104
86a
108a
108
108b

FIG. 4B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78
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94b
73
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106b
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84
88a
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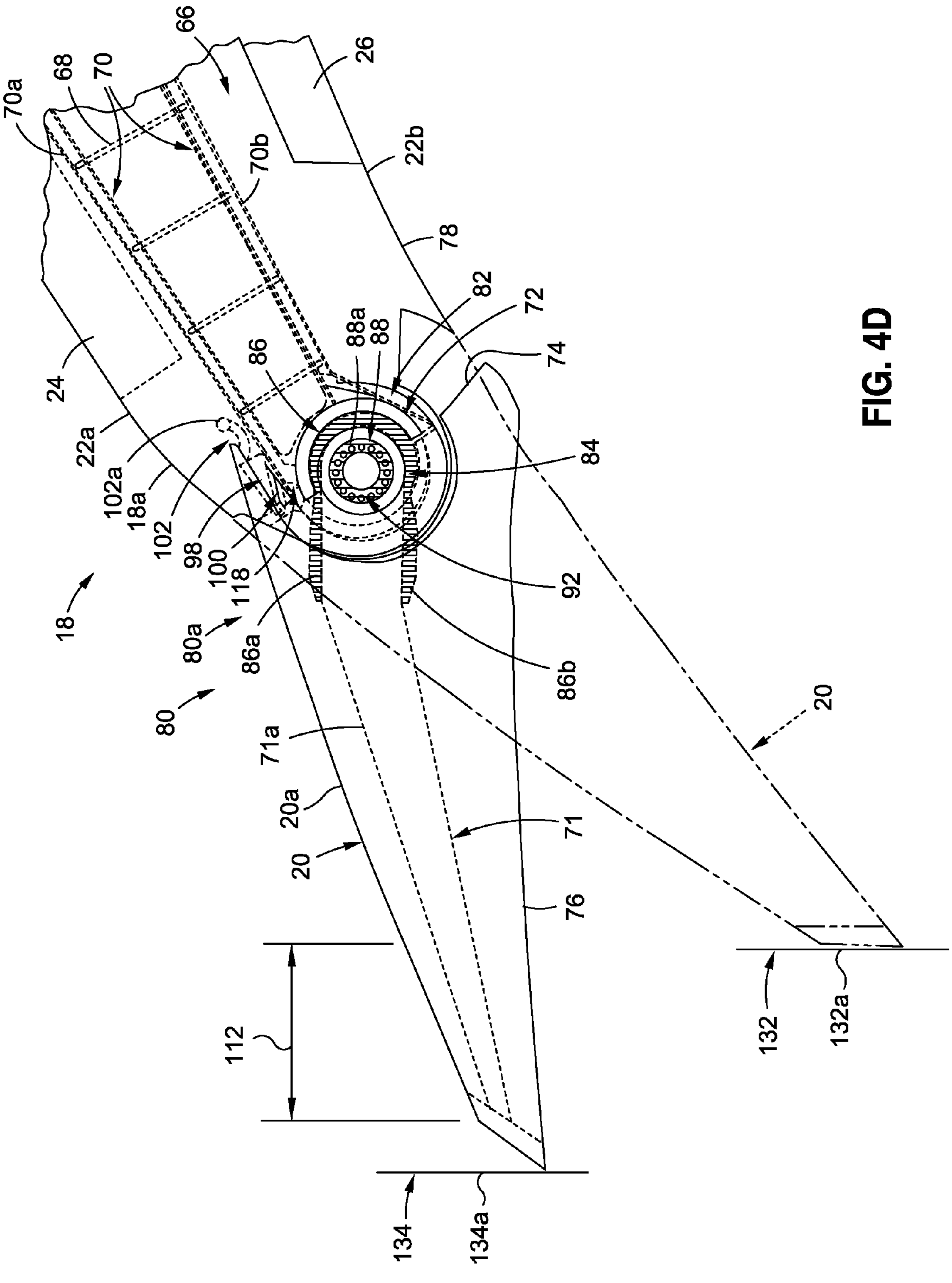
104
108a
108
108b
76

FIG. 4C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72
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98
100
118
84
92
18
80a
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86b
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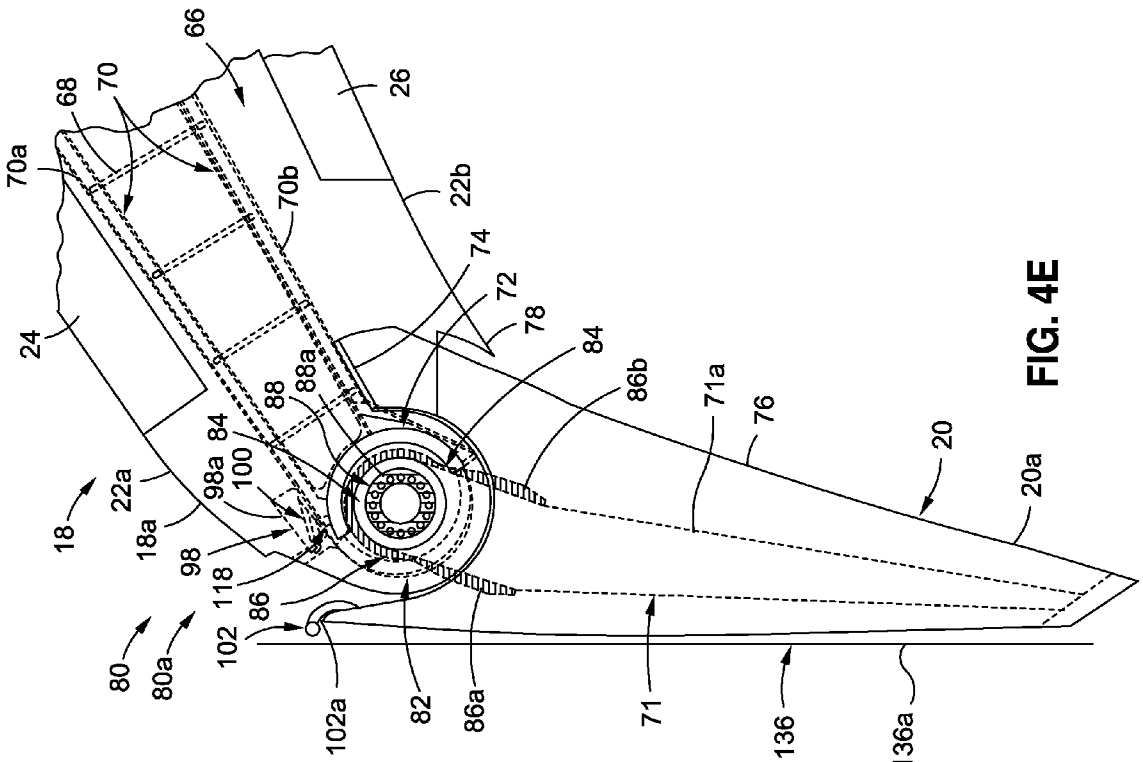
20
71a
20a
71
76
112
132
132a
134
134a

FIG. 4D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84
71a
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20
20a
18
22a
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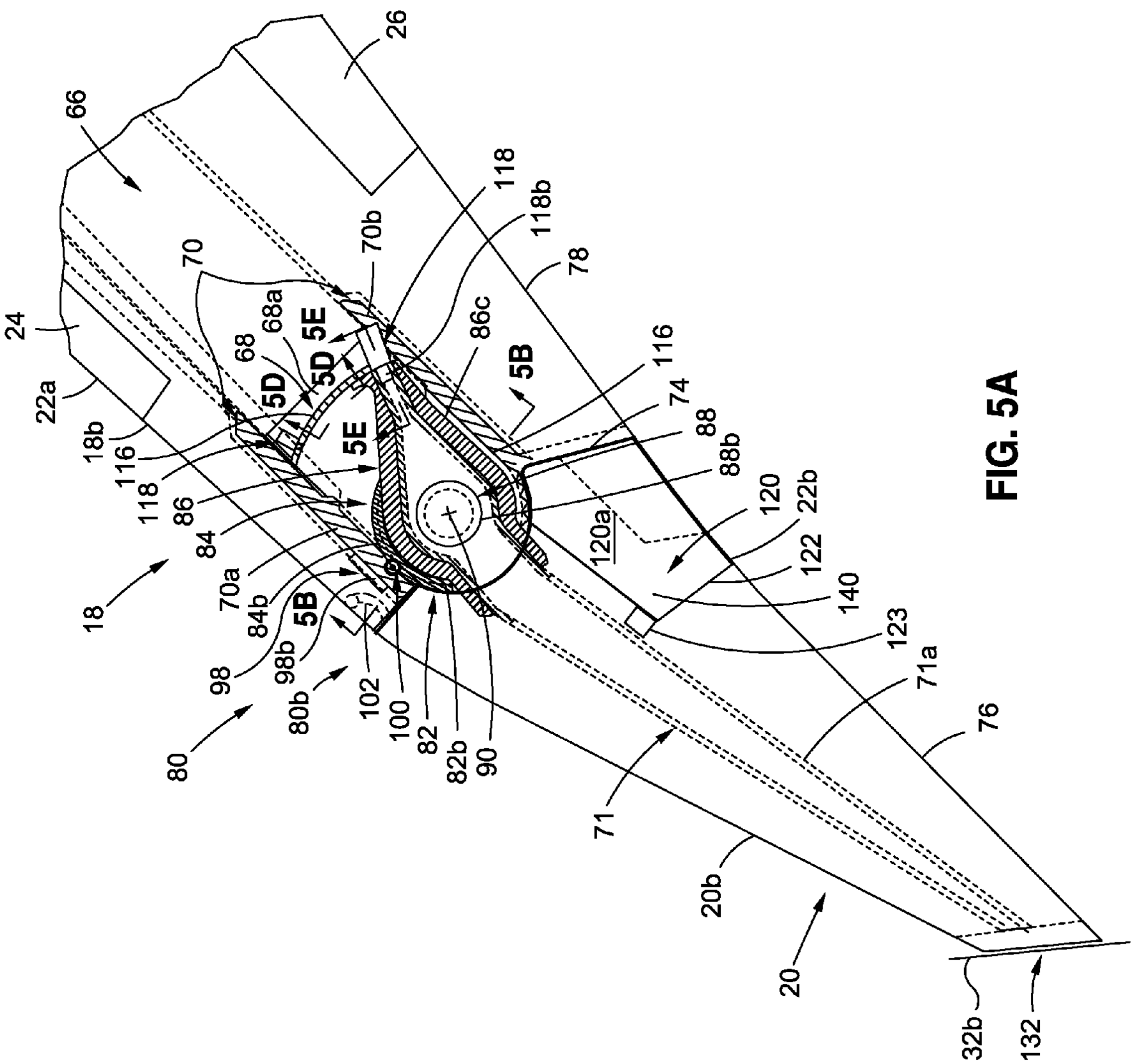
18a
98
118
86
80
80a
102
102a
82
86a
71
136
136a

FIG. 4E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70b
68a
68
5E
5D
118
118b
86c
78
5B
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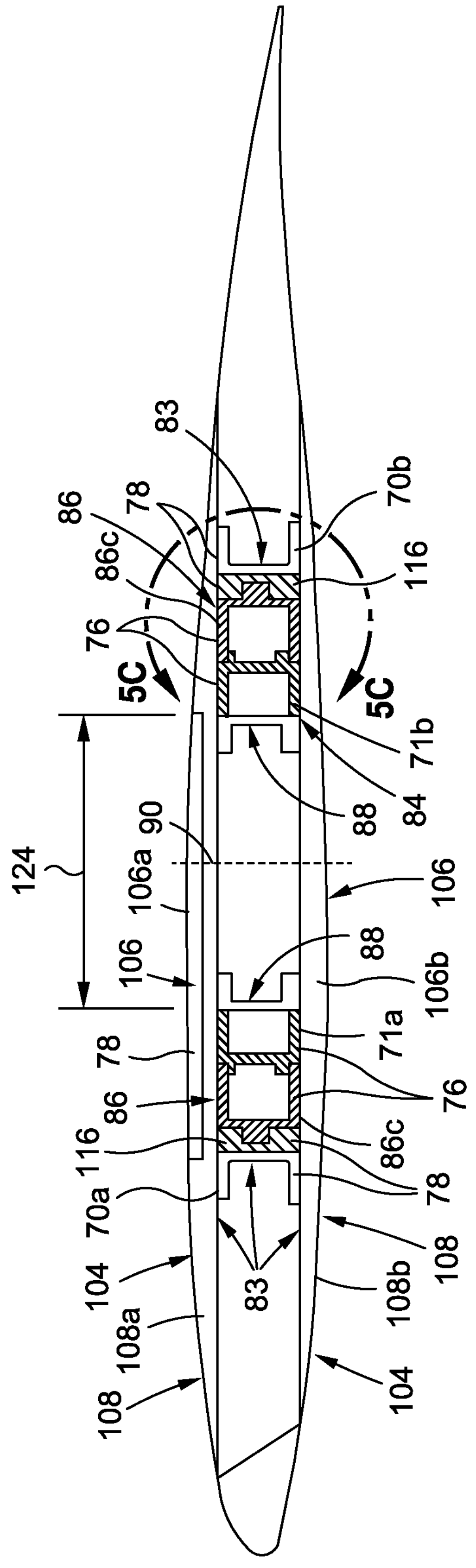
74
88
88b
120
22b
122
140
123
120a
116
118
86
84
18
70a
84b
5B
98
98b
80b
80
102
100
82
82b
90
5E
5D
71a
76
71
20b
20
132b
132

FIG. 5A


83
70b
78
86
86c
116
76
5C
5C
71b
84
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124
90
106a
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106
88
106b
106
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86
86c
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70a
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104
83
108b
108a
104
108

FIG. 5B

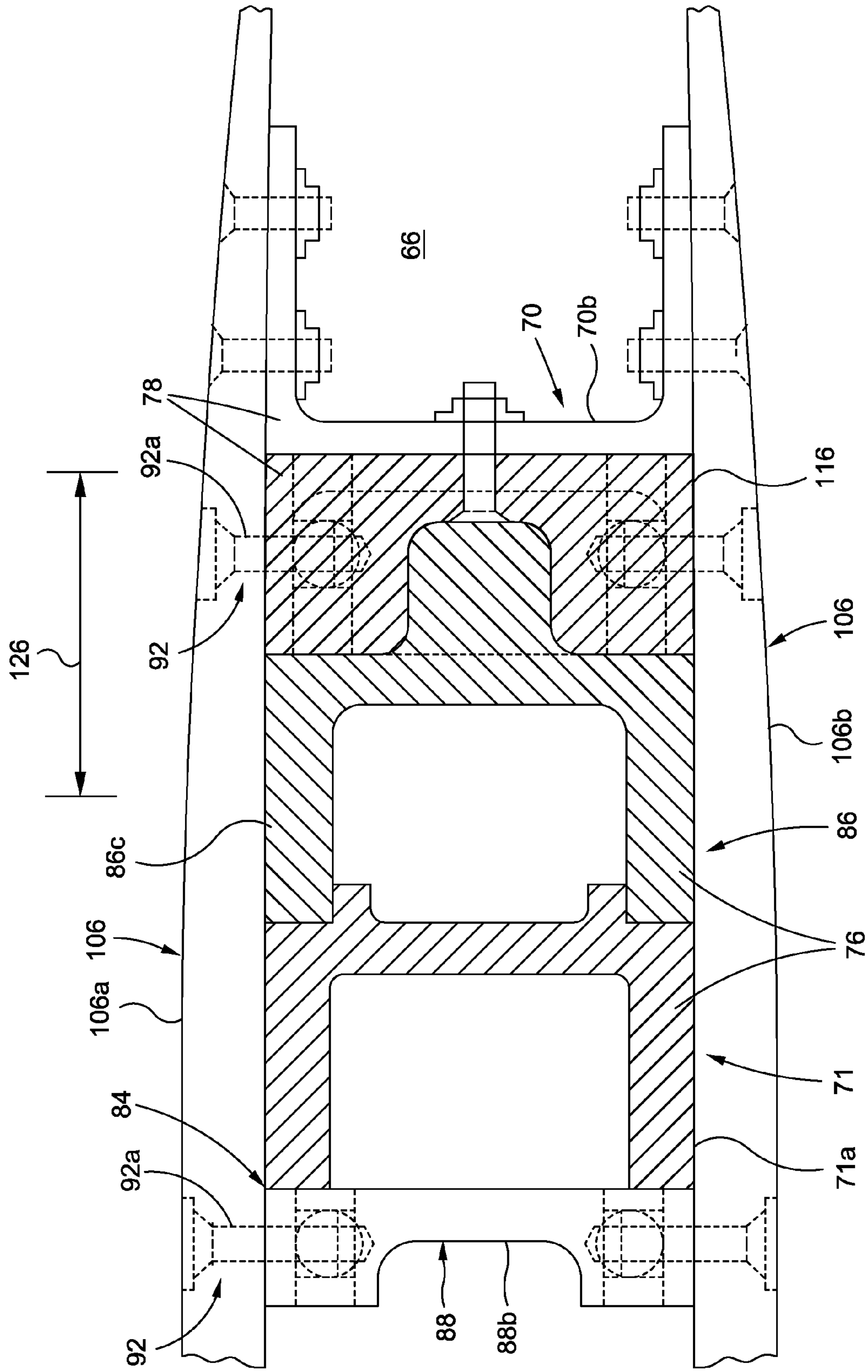
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FIG. 5C

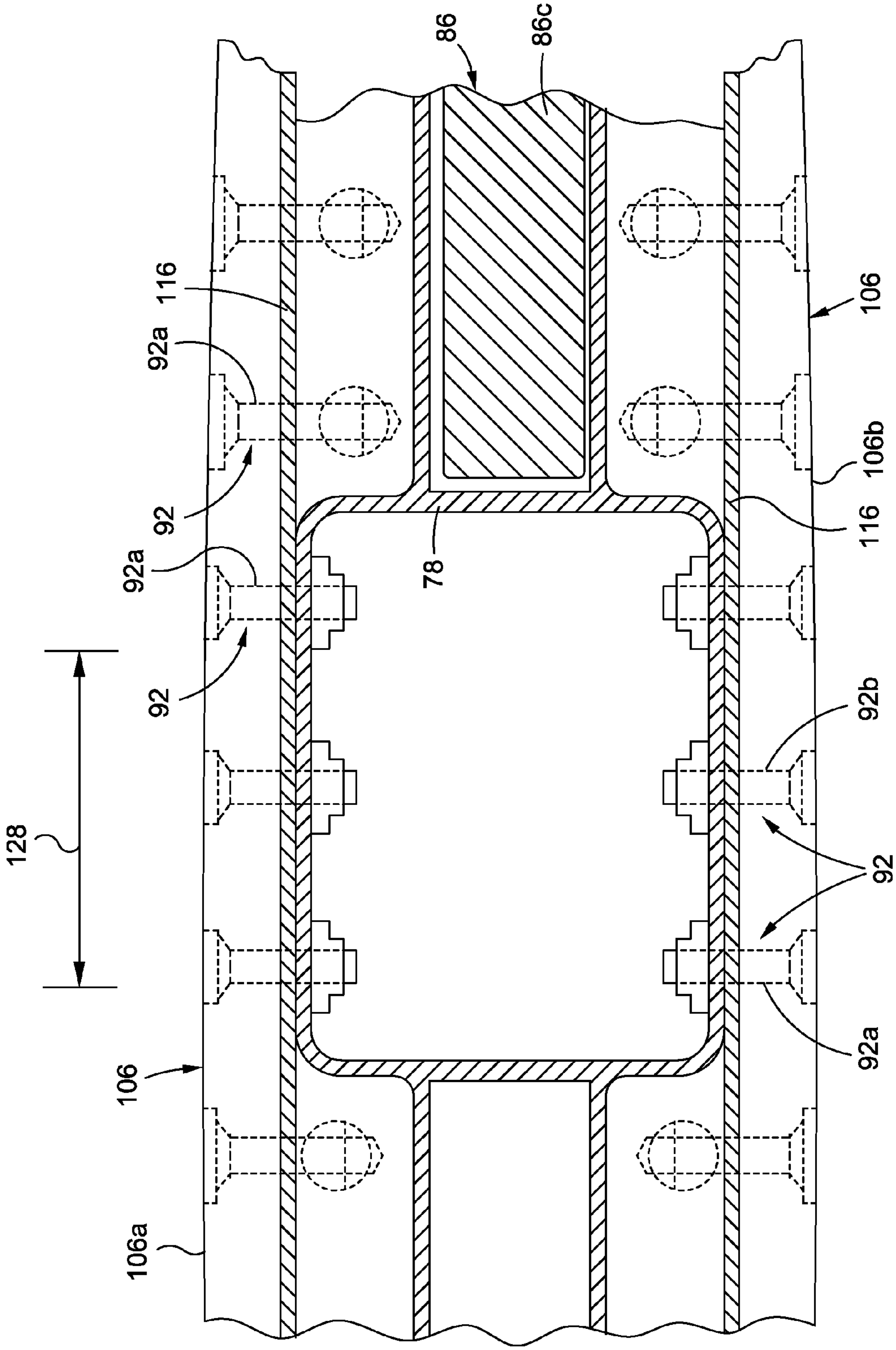



FIG. 5D

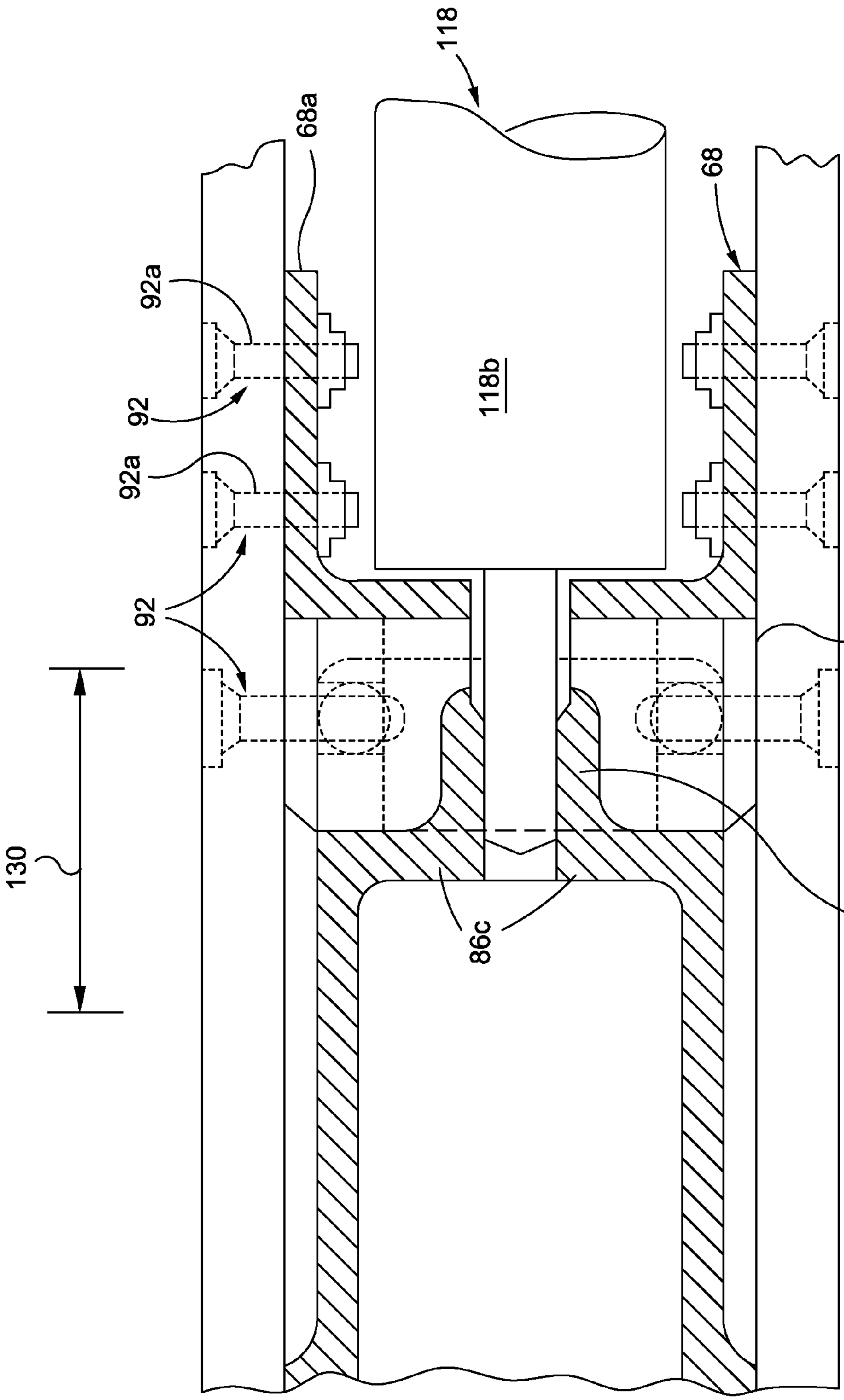
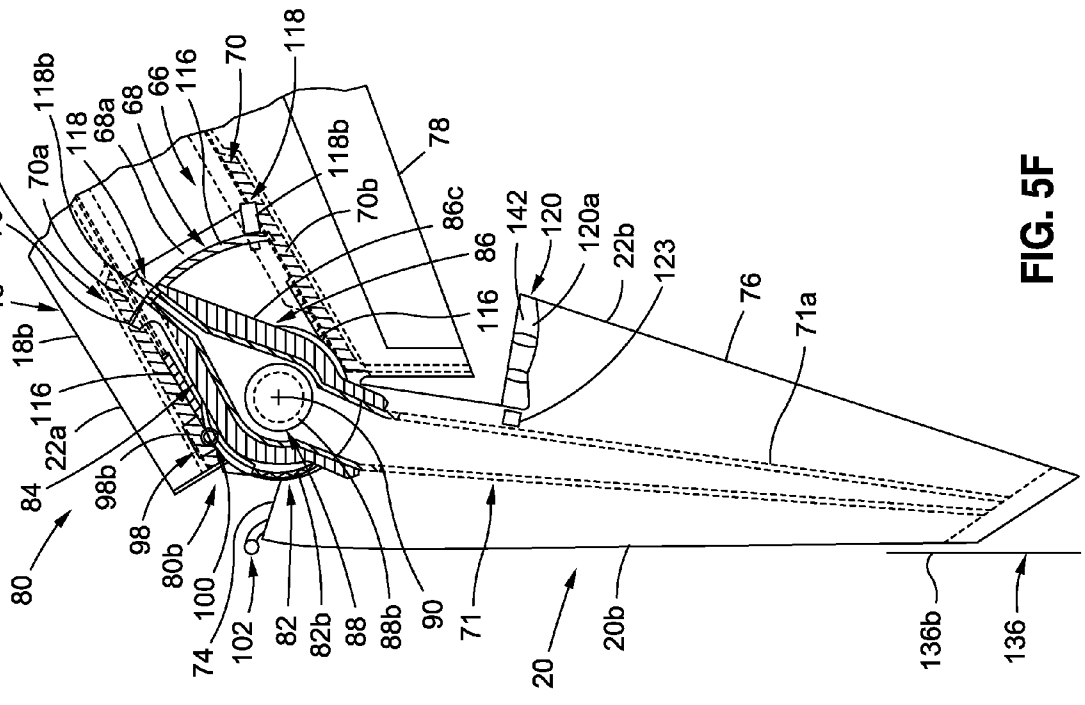



FIG. 5E



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20b
136b
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73
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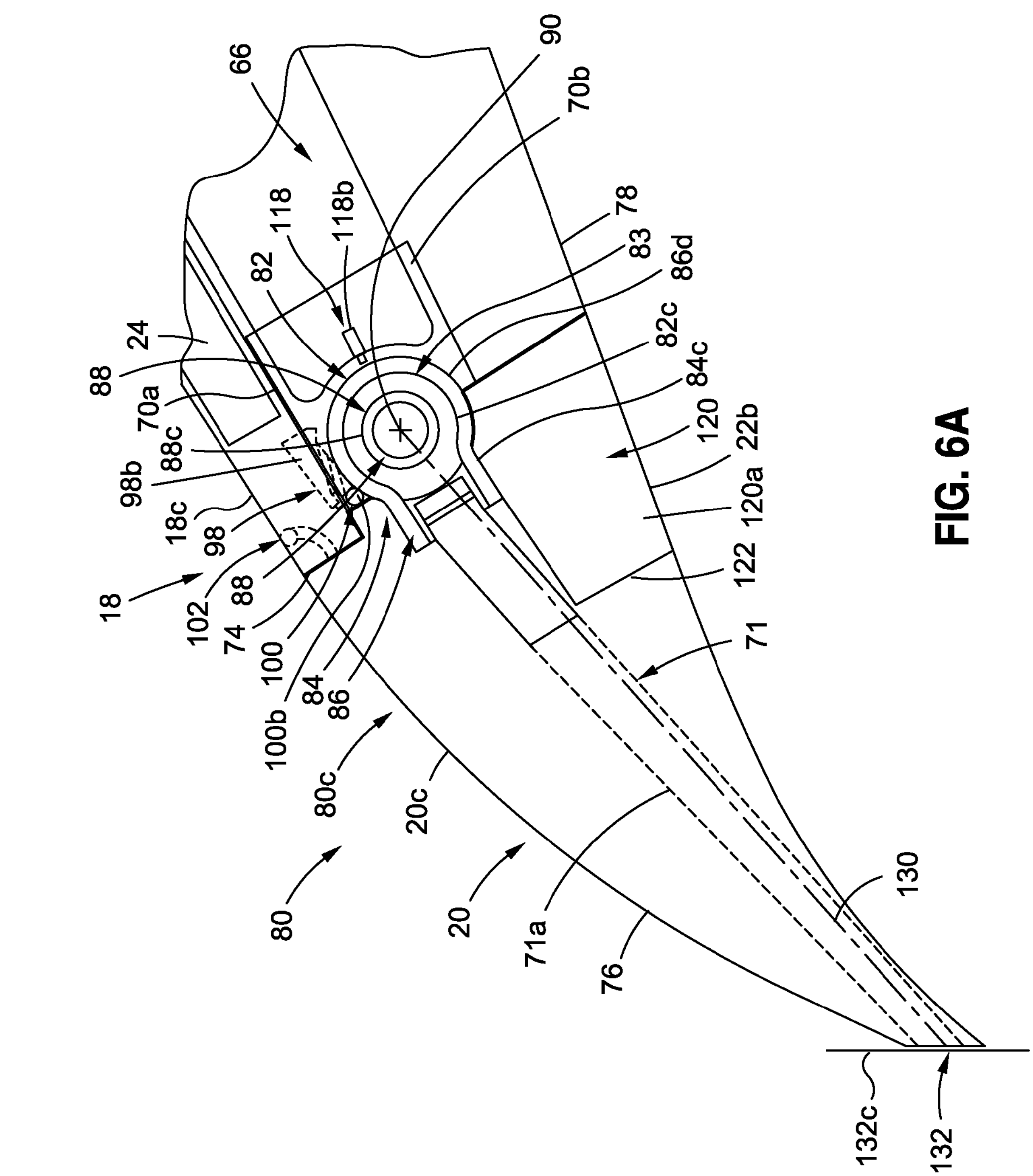
FIG. 5F



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18c
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132c
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FIG. 6A

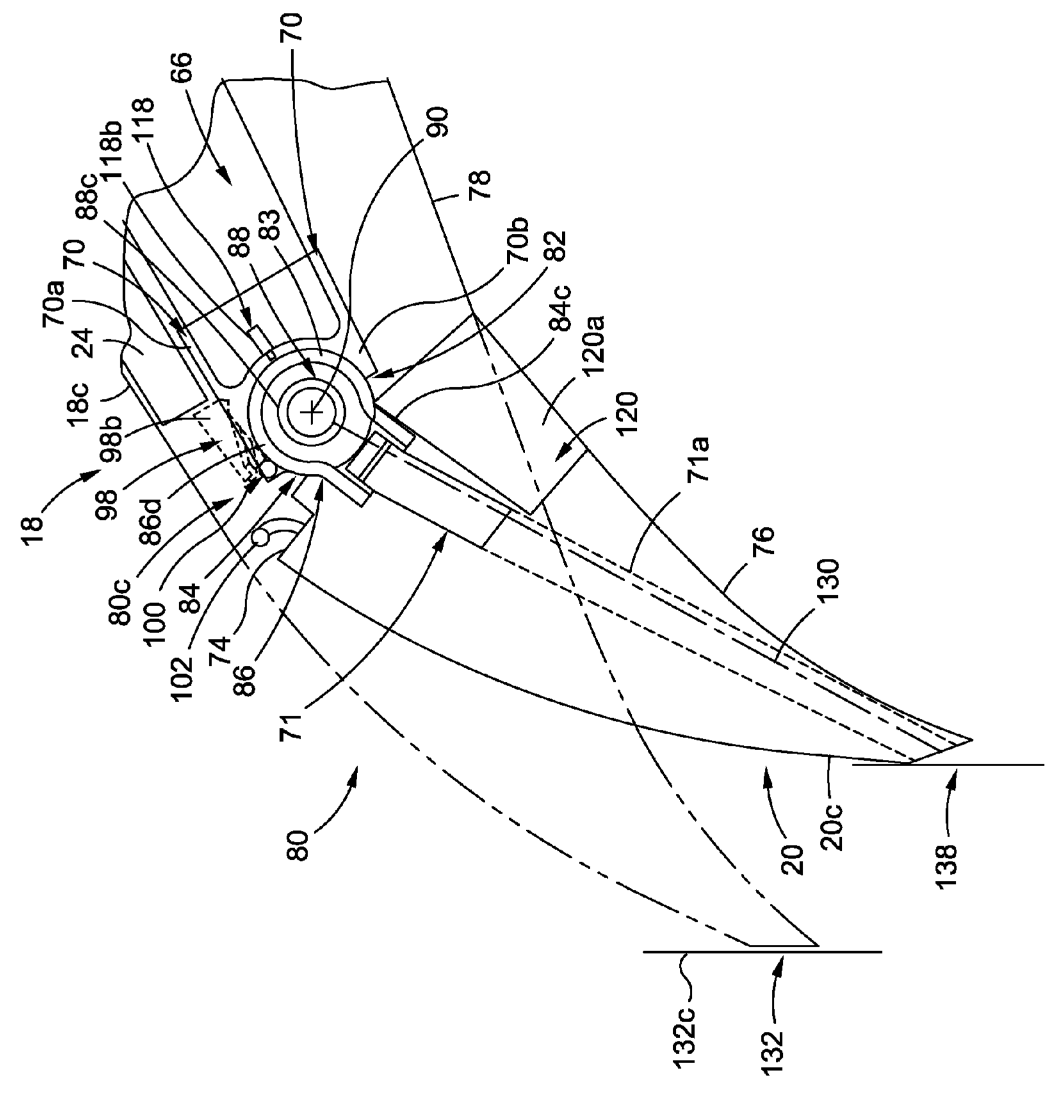
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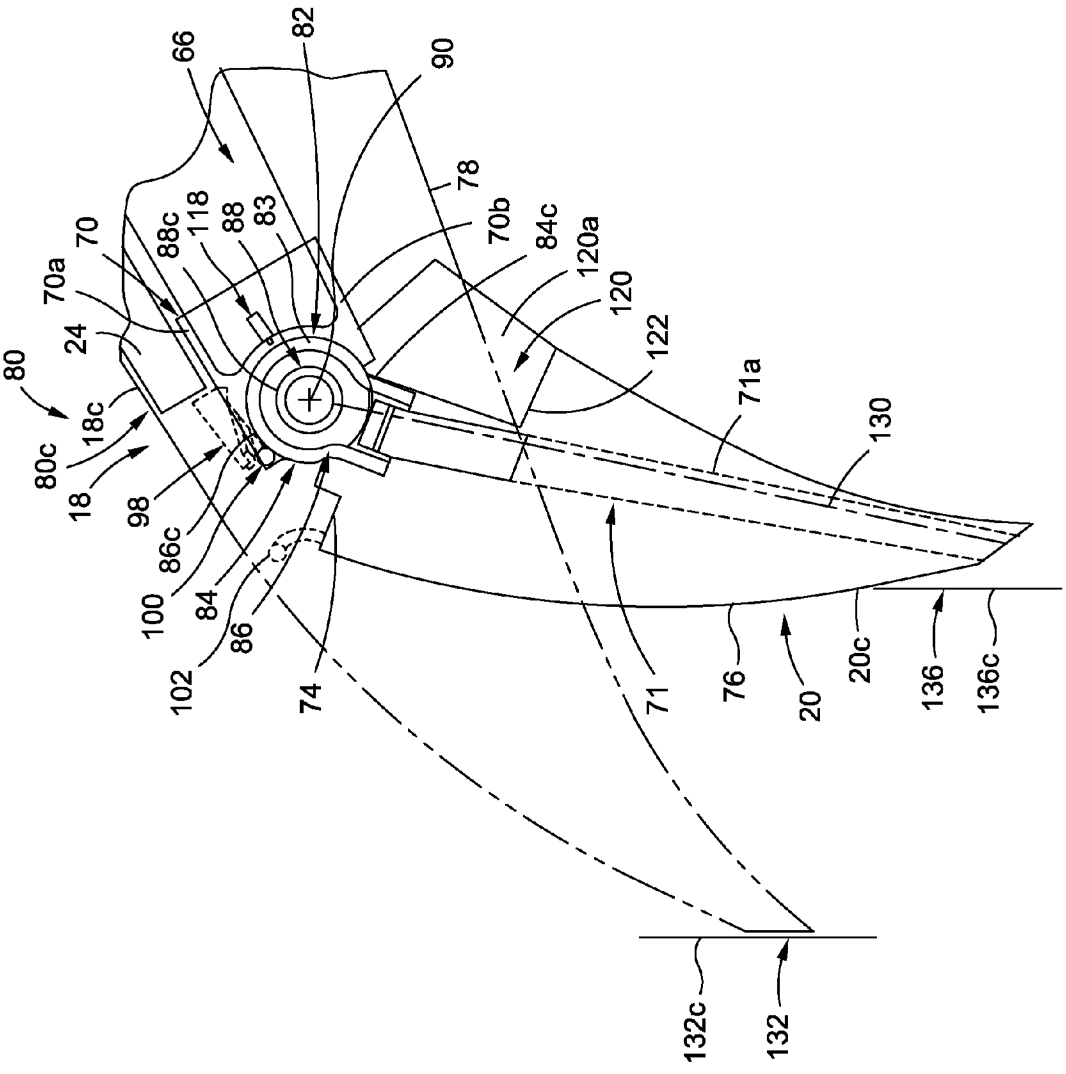
FIG. 6B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18c
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136c
132c
132

FIG. 6C

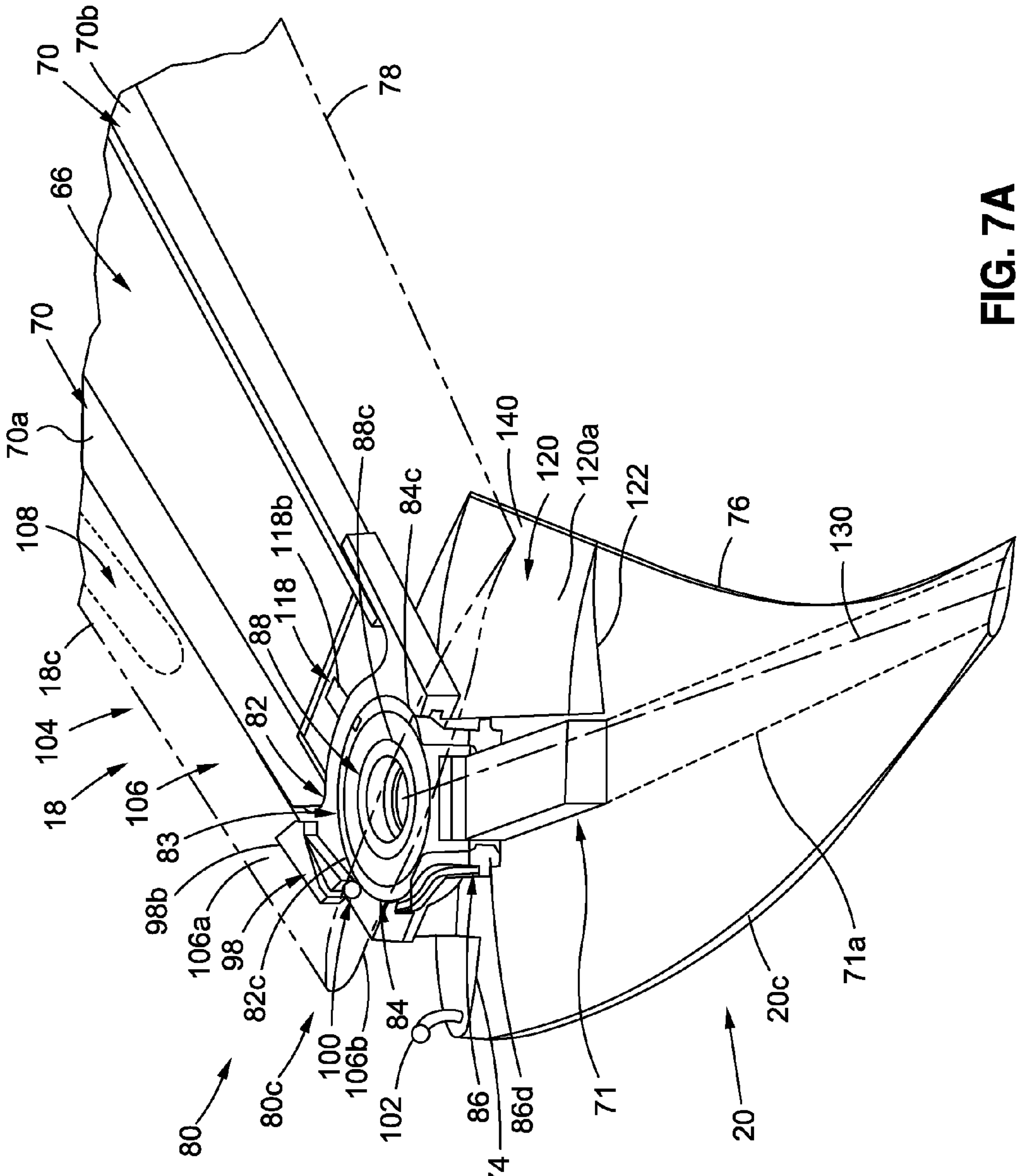
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FIG. 7A

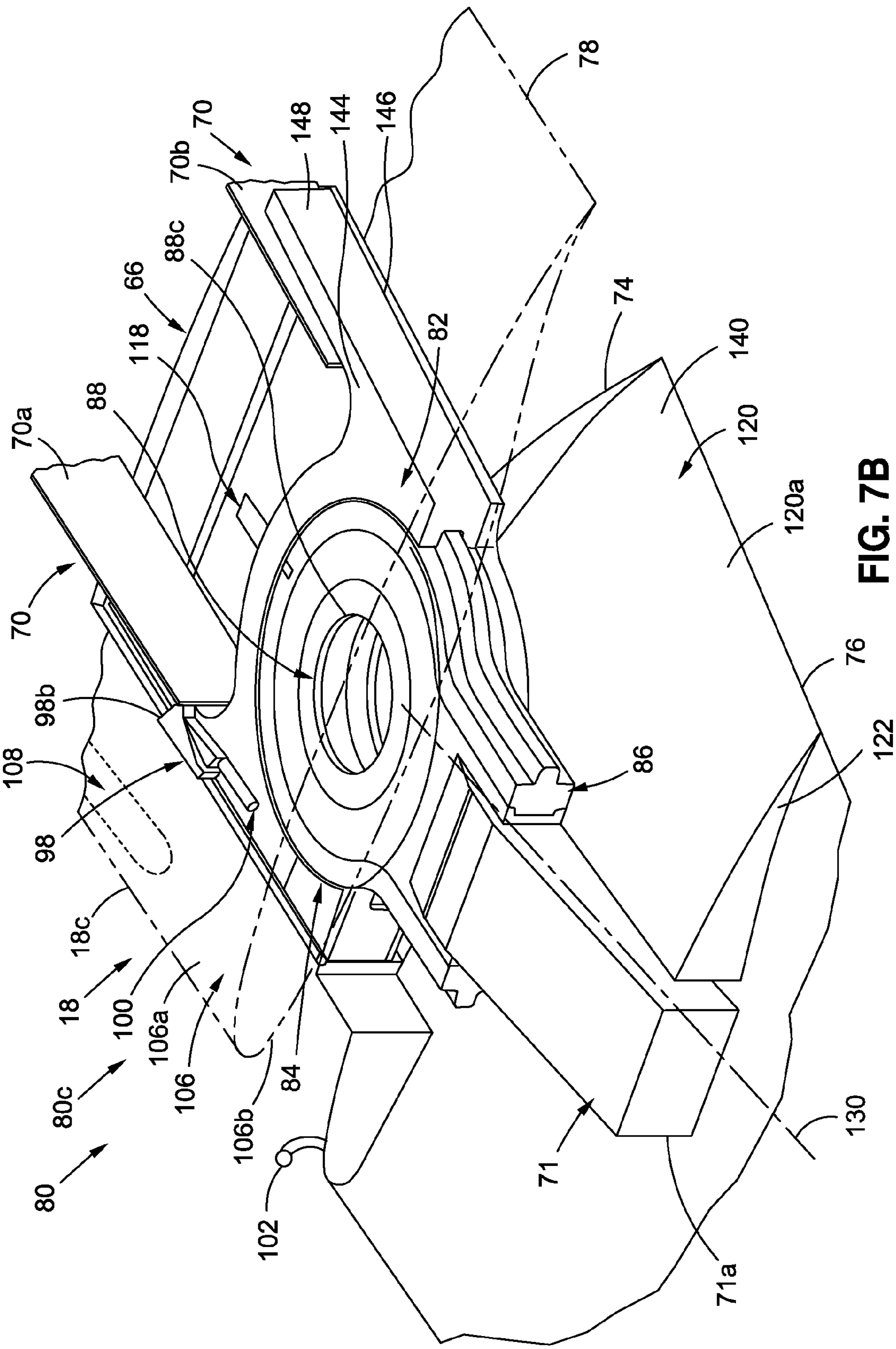
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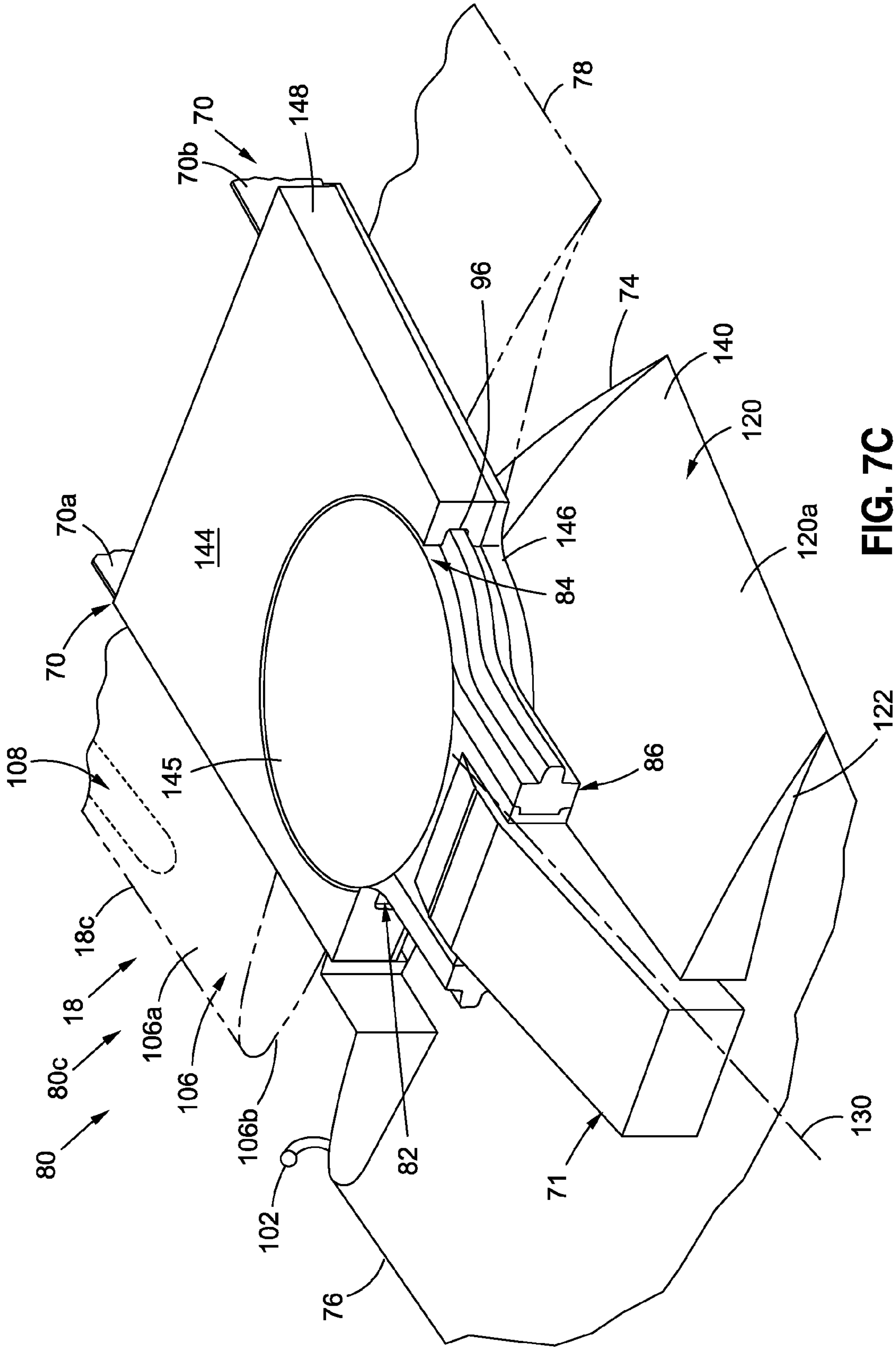
FIG. 7B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18c
18
80c
106a
106
106b
80
82
102
71
130
76

FIG. 7C

200

OPERATIVELY COUPLING A SWING WING TIP ASSEMBLY TO A WING OF AN AIR VEHICLE, THE SWING WING TIP ASSEMBLY COMPRISING: AN UNFIXED WING TIP PORTION MOVABLY CONNECTED TO A FIXED WING PORTION OF THE WING; AND, A DUAL LOAD PATH STRUCTURE COMPRISING: DUAL WING SKIN PLATES AND A ROTATION JOINT COUPLED BETWEEN THE DUAL WING SKIN PLATES, THE ROTATION JOINT COMPRISING: A DUAL ROTATION PIN ELEMENT HAVING A CENTER AXIS AND DUAL ROTATION ELEMENTS CONFIGURED TO ROTATE ABOUT THE CENTER ROTATION AXIS — 202

↓

OPERATIVELY COUPLING AN ACTUATOR ASSEMBLY TO THE ROTATION JOINT — 204

↓

OPERATIVELY COUPLING A CONTROLLER SYSTEM TO THE ACTUATOR ASSEMBLY TO CONTROL THE ACTUATOR ASSEMBLY TO ACTUATE THE ROTATION JOINT — 206

↓

TRANSFERRING LOAD FROM THE UNFIXED WING TIP PORTION TO THE FIXED WING PORTION VIA THE DUAL LOAD PATH STRUCTURE TO PROVIDE FAIL-SAFE LOAD PATHS FOR THE WING — 208

↓

OPTIONALLY, ROTATING THE UNFIXED WING TIP PORTION WITH RESPECT TO THE FIXED WING PORTION ABOUT THE CENTER ROTATION AXIS AT A SELECTED OPERATION CONDITION — 210

↓

OPTIONALLY, OPERATIVELY COUPLING A NAVIGATION ELEMENT NEAR A HINGE LINE BETWEEN THE FIXED WING PORTION AND THE UNFIXED WING TIP PORTION TO BE EXPOSED AND ACTIVATED IN RESPONSE TO ROTATION OF THE UNFIXED WING TIP PORTION — 212

↓

OPTIONALLY, MOVING A MOVING PANEL POSITIONED NEAR A TRAILING EDGE OF THE UNFIXED WING TIP PORTION BEFORE ROTATING THE UNFIXED WINGTIP PORTION — 214

↓

OPTIONALLY, MAINTAINING THE UNFIXED WING TIP PORTION WITHOUT ROTATION TO PROVIDE AN UNFOLDED FLIGHT CONDITION — 216

**FIG. 8**

# SWING WING TIP SYSTEM, ASSEMBLY AND METHOD WITH DUAL LOAD PATH STRUCTURE

## CROSS REFERENCE TO RELATED APPLICATIONS

This nonprovisional patent application is related to U.S. nonprovisional patent application Ser. No. 13/530,089, titled “SWING TIP ASSEMBLY ROTATION JOINT”, filed on Jun. 21, 2012, and this nonprovisional patent application is also related to U.S. nonprovisional patent application Ser. No. 13/964,072, titled “HORIZONTAL FOLDING WINGTIP”, filed on Aug. 10, 2013. The contents of both of these filed U.S. nonprovisional patent applications are hereby incorporated by reference in their entireties.

## BACKGROUND

1) Field of the Disclosure

The disclosure relates generally to wing systems, assemblies, and methods for air vehicles, and more particularly, to wing tip systems, assemblies, and methods having dual load path structures for air vehicles, such as aircraft.

2) Description of Related Art

Designing an aircraft having a configuration to improve fuel efficiency is an important consideration as fuel costs increase. Increasing or lengthening the wingspan of an aircraft may be used to increase performance of the aircraft, such as lift-to-drag efficiency performance, which may, in turn, improve fuel efficiency. Thus, aircraft with longer wingspans may be more performance efficient than aircraft with shorter wingspans.

However, increasing or lengthening the wingspan of an aircraft to increase aircraft performance may limit or prevent the aircraft’s use at airports having size restrictions with respect to airport gates, taxiways, runways, or other infrastructure. Airports with airport gates, taxiways, runways, and other infrastructure constructed for one generation of aircraft may be too small to accommodate later generations of aircraft having increased wingspans. For example, such airports may be limited to aircraft with a wingspan length of 213 feet or smaller, i.e., tip-to-tip wingspan, at the airport gates or on the airport taxiways and runways or other infrastructure. The airport gates, taxiways, runways and other infrastructure of airports having such size restrictions would have to be modified to allow aircraft with an increased wingspan to travel and operate at the airport gates or on the airport taxiways and runways. However, modifying or reconfiguring such airport infrastructure, including gates, taxiways, and runways, may be an expensive and time consuming undertaking.

In addition to improved fuel efficiency as a design consideration for aircraft, providing fail-safe load paths for primary load carrying members, such as wings, of an aircraft may also be an important design consideration. As used herein, “fail-safe” means a structure, system, assembly, and/or method having a redundant feature, for example, a redundant load path, which in the event of a failure in one load path to carry the load, a second load path is configured to carry the load. Known wing structures for aircraft exist having wing tip systems that fold to shorten the wingspan and unfold to lengthen the wingspan. However, such known wing structures may only have a single load path.

Thus, it is desirable to provide an aircraft having wing structures with fail-safe load paths, such as dual load paths, while also having wing structures with folding wing tips to



reduce and expand the wingspan of the aircraft in order to be able to operate at an airport having size restrictions with respect to aircraft wingspan.

Accordingly, there is a need in the art for an improved wing tip system, assembly, and method that provide advantages over known wing tip systems, assemblies, and methods.

## SUMMARY

This need for an improved wing tip system, assembly, and method is satisfied. As discussed in the below detailed description, embodiments of the improved wing tip system, assembly, and method may provide significant advantages over known wing tip systems, assemblies, and methods.

In one embodiment of the disclosure, there is provided a swing wing tip system for an air vehicle. The swing wing tip system comprises a swing wing tip assembly. The swing wing tip assembly comprises an unfixed wing tip portion movably connected to a fixed wing portion of a wing of an air vehicle. The swing wing tip assembly further comprises a dual load path structure configured to transfer load from the unfixed wing tip portion to the fixed wing portion. The dual load path structure comprises dual wing skin plates and a rotation joint coupled between the dual wing skin plates and configured to rotationally couple the unfixed wing tip portion to the fixed wing portion. The rotation joint comprises a dual rotation pin element have a center rotation axis and dual rotation elements configured to rotate about the center rotation axis.

The swing wing tip system further comprises an actuator assembly operatively coupled to the rotation joint to actuate the rotation joint, enabling rotation of the unfixed wing tip portion with respect to the fixed wing portion about the center rotation axis at a selected operation condition. The swing wing tip system further comprises a controller system operatively coupled to the actuator assembly to control actuation of the rotation joint and rotation of the unfixed wing tip portion.

In another embodiment of the disclosure, there is provided an aircraft having fail-safe load paths for one or more wings. The aircraft comprises at least one fuselage and at least one wing having a swing wing tip assembly. The swing wing tip assembly comprises an unfixed wing tip portion movably connected to a fixed wing portion of the one or more wings.

The swing wing tip assembly further comprises a dual load path structure providing fail-safe load paths for the one or more wings and configured to transfer load from the unfixed wing tip portion to the fixed wing portion. The dual load path structure comprises dual wing skin plates comprising an upper wing skin and a lower wing skin. Each wing skin has a plate portion attached to the wing skin.

The dual load path structure further comprises a rotation joint coupled between the dual wing skin plates and configured to rotationally couple the unfixed wing tip portion to the fixed wing portion. The rotation joint comprises a dual rotation pin element having a center rotation axis and dual rotation elements configured to rotate about the center rotation axis. The dual load path structure further comprises dual channel segments coupled between the dual wing skin plates.

The one or more wings further comprises an actuator assembly operatively coupled to the rotation joint to actuate the rotation joint, enabling rotation of the unfixed wing tip portion with respect to the fixed wing portion about the center rotation axis at a selected operation condition. The one or more wings further comprises a controller system operatively coupled to the actuator assembly to control actuation of the rotation joint and rotation of the unfixed wing tip portion. The one or more wings further comprises a navigation element positioned near a hinge line between the fixed wing portion and the unfixed wing tip portion and operable to be exposed and activated in response to rotation of the unfixed wing tip portion.

In another embodiment of the disclosure, there is provided a method for providing fail-safe load paths for a wing of an air vehicle. The method comprises the step of operatively coupling a swing wing tip assembly to a wing of an air vehicle. The swing wing tip assembly comprises an unfixed wing tip portion movably connected to a fixed wing portion of the wing, and a dual load path structure. The dual load path structure comprises dual wing skin plates and a rotation joint coupled between the dual wing skin plates. The rotation joint comprises a dual rotation pin element having a center rotation axis and dual rotation elements configured to rotate about the center rotation axis.

The method further comprises the step of operatively coupling an actuator assembly to the rotation joint. The method further comprises the step of operatively coupling a controller system to the actuator assembly to control the actuator assembly to actuate the rotation joint. The method further comprises the step of transferring load from the unfixed wing tip portion to the fixed wing portion via the dual load path structure to provide fail-safe load paths for the wing.

The features, functions, and advantages that have been discussed can be achieved independently in various embodiments of the disclosure or may be combined in yet other embodiments further details of which can be seen with reference to the following description and drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

The disclosure can be better understood with reference to the following detailed description taken in conjunction with the accompanying drawings, which are provided to facilitate understanding of the disclosure without limiting the breadth, scope, scale, or applicability of the disclosure, and which illustrate preferred and exemplary embodiments, but which are not necessarily drawn to scale, wherein:

FIG. **1** is an illustration of a perspective view of an air vehicle incorporating an exemplary embodiment of a swing wing tip system of the disclosure;

FIG. **2**A is an illustration of a flow diagram of an exemplary aircraft manufacturing and service method;

FIG. **2**B is an illustration of an exemplary block diagram of an aircraft;

FIG. **3**A is an exemplary block diagram of a swing wing tip system and a swing wing tip assembly according to one or more embodiments of the disclosure;

FIG. **3**B is an exemplary block diagram of an actuator assembly and a controller system that may be used in one or more embodiments of a swing wing tip system according to the disclosure;

FIG. **4**A is an illustration of a cutaway top plan view of a wing in an unfolded flight position having an embodiment of a swing wing tip system and a swing wing tip assembly according to the disclosure;

FIG. **4**B is an illustration of a cross-sectional view taken along lines **4**B-**4**B of FIG. **4**A;

FIG. **4**C is an illustration of a cross-sectional view taken along lines **4**C-**4**C of FIG. **4**A;

FIG. **4**D is an illustration of a cutaway top plan view of the wing of FIG. **4**A showing forward rotation from an unfolded flight position to a forward folded flight position;

FIG. **4**E is an illustration of a cutaway top plan view of the wing of FIG. **4**A in an aft folded ground position;

FIG. **5**A is an illustration of a cutaway top plan view of a wing in an unfolded flight position having another embodiment of a swing wing tip system and a swing wing tip assembly according to the disclosure;

FIG. **5**B is an illustration of a cross-sectional view taken along lines **5**B-**5**B of FIG. **5**A;

FIG. **5**C is an illustration of a close-up view of circle **5**C of FIG. **5**B;

FIG. **5**D is an illustration of a close-up cross-sectional view taken along lines **5**D-**5**D of FIG. **5**A;

FIG. **5**E is an illustration of a close-up cross-sectional view taken along lines **5**E-**5**E of FIG. **5**A;

FIG. **5**F is an illustration of a cutaway top plan view of the wing of FIG. **5**A in an aft folded ground position;

FIG. **6**A is an illustration of a cutaway top plan view of a wing in an unfolded flight position having yet another embodiment of a swing wing tip system and a swing wing tip assembly according to the disclosure;

FIG. **6**B is an illustration of a cutaway top plan view of the wing of FIG. **6**A showing the wing in an aft folded transition position from an unfolded flight position;

FIG. **6**C is an illustration of a cutaway top plan view of the wing of FIG. **6**A showing aft rotation of the wing from an unfolded flight position to an aft folded ground position;

FIG. **7**A is an illustration of a cutaway top perspective view of the wing of FIG. **6**A showing the wing folded aft;

FIG. **7**B is an illustration of a close-up cutaway top perspective view of an embodiment of the rotation joint of FIG. **7**A;

FIG. **7**C is an illustration of a close-up top perspective view of the rotation joint of FIG. **7**B showing a top plate over the rotation joint; and,

FIG. **8** is an illustration of a flow diagram of an exemplary embodiment of a method of the disclosure.

## DETAILED DESCRIPTION

Disclosed embodiments will now be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all of the disclosed embodiments are shown. Indeed, several different embodiments may be provided and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete and will fully convey the scope of the disclosure to those skilled in the art.

Now referring to the Figures, FIG. **1** is an illustration of a perspective view of an air vehicle **10** incorporating an exemplary embodiment of a swing wing tip system **80** of the disclosure. As shown in FIG. **1**, the air vehicle **10**, such as in the form of aircraft **11**, comprises a fuselage **12**, engines **14**, a tail **16** with horizontal stabilizers **16***a* and a vertical stabilizer **16***b*, wings **18**, such as in the form of swing wings **18***a*, and wing tips **20**, such as in the form of swing wing tips **20***a*. As further shown in FIG. **1**, the air vehicle **10** has a wingspan **21** spanning the distance between the wing tips **20**. As further shown in FIG. **1**, each wing **18**, such as in the form of swing wing **18***a*, may comprise a leading edge **22***a*, a trailing edge **22***b* and control surfaces such as slats **24**, ailerons **26**, and flaps **28**. The control surfaces may further comprise, for example but without limitation, an elevator, a spoiler, an elevon, or other control surface.

Although the air vehicle **10**, such as aircraft **11**, shown in FIG. **1** is generally representative of a commercial passenger aircraft having one or more wings **18** with one or more embodiments of the swing wing tip system **80**, the teachings of the disclosed embodiments may be applied to other passenger aircraft, cargo aircraft, military aircraft, rotorcraft, and other types of aircraft or air vehicles having one or more wings.

FIG. **2** is an illustration of a flow diagram of an exemplary aircraft manufacturing and service method **30**. FIG. **3** is an illustration of an exemplary block diagram of an aircraft **50**. Referring to FIGS. **2-3**, embodiments of the disclosure may be described in the context of the aircraft manufacturing and service method **30** as shown in FIG. **2** and the aircraft **50** as shown in FIG. **3**. During pre-production, exemplary aircraft manufacturing and service method **30** may include specification and design **32** of the aircraft **50** and material procurement **34**. During manufacturing, component and subassembly manufacturing **36** and system integration **38** of the aircraft **50** takes place. Thereafter, the aircraft **50** may go through certification and delivery **40** in order to be placed in service **42**. While in service **42** by a customer, the aircraft **50** may be scheduled for routine maintenance and service **44** (which may also include modification, reconfiguration, refurbishment, and other suitable services).

Each of the processes of the aircraft manufacturing and service method **30** may be performed or carried out by a system integrator, a third party, and/or an operator (e.g., a customer). For the purposes of this description, a system integrator may include, without limitation, any number of aircraft manufacturers and major-system subcontractors; a third party may include, without limitation, any number of vendors, subcontractors, and suppliers; and an operator may include an airline, leasing company, military entity, service organization, and other suitable operators.

As shown in FIG. **3**, the aircraft **50** produced by the exemplary aircraft manufacturing and service method **30** may include an airframe **52** with a plurality of systems **54** and an interior **56**. Examples of high-level systems **54** may include one or more of a propulsion system **58**, an electrical system **60**, a hydraulic system **62**, and an environmental system **64**. Any number of other systems may be included. Although an aerospace example is shown, the principles of the invention may be applied to other industries, such as the automotive industry.

Methods and systems embodied herein may be employed during any one or more of the stages of the aircraft manufacturing and service method **30**. For example, components or subassemblies corresponding to component and subassembly manufacturing **36** may be fabricated or manufactured in a manner similar to components or subassemblies produced while the aircraft **50** is in service. Also, one or more apparatus embodiments, method embodiments, or a combination thereof, may be utilized during component and subassembly manufacturing **36** and system integration **38**, for example, by substantially expediting assembly of or reducing the cost of the aircraft **50**. Similarly, one or more of apparatus embodiments, method embodiments, or a combination thereof, may be utilized while the aircraft **50** is in service, for example and without limitation, to maintenance and service **44**.

In one embodiment of the disclosure, there is provided a swing wing tip system **80** (see FIGS. **3**A, **4**A, **5**A, **6**A) for an air vehicle **10** (see FIGS. **1**, **3**A). The swing wing tip system **80** (see FIGS. **3**A, **4**A, **5**A, **6**A) comprises a swing wing tip assembly **82** (see FIGS. **3**A, **4**A, **5**A, **6**A). FIG. **3**A is an exemplary block diagram of the swing wing tip system **80** and the swing wing tip assembly **82** according to one or more embodiments of the disclosure.

As shown in FIG. **3**A, the swing wing tip system **80** comprises the swing wing tip assembly **82**, an actuator assembly **98** and a controller system **150**. FIG. **3**B is an exemplary block diagram of the actuator assembly **98** and the controller system **150** that may be used in one or more embodiments of the swing wing tip system **80** according to the disclosure.

As further shown in FIG. **3**A, the swing wing tip assembly **82** comprises a fixed wing portion **78**, an unfixed wing tip portion **76**, and a dual load path structure **83**. The unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) is preferably movably connected to the fixed wing portion **78** (see FIGS. **3**A, **4**A, **5**A, **6**A) of the wing **18** (see FIGS. **3**A, **4**A, **5**A, **6**A) of the air vehicle **10** (see FIGS. **1**, **3**A), such as aircraft **11** (see FIGS. **1**, **3**A).

The dual load path structure **83** (see FIGS. **3**A, **4**B, **5**B, **6**A) is preferably configured to transfer load from the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) to the fixed wing portion **78** (see FIGS. **3**A, **4**A, **5**A, **6**A). Load is preferably transferred from the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) to the fixed wing portion **78** (see FIGS. **3**A, **4**A, **5**A, **6**A) via the dual load path structure **83** (see FIGS. **3**A, **4**B, **5**B, **6**A) to provide fail-safe load paths **160** (see FIG. **3**A) for primary load carrying members, such as the wings **18** (see FIGS. **1**, **3**A, **4**A, **5**A, **6**A) of the air vehicle **10** (see FIGS. **1**, **3**A). As discussed above, "fail-safe" means a structure, system, assembly, and/or method having a redundant feature, for example, a redundant load path, which in the event of a failure in one load path to carry the load, a second load path is configured to carry the load. The dual load path structure **83** (see FIGS. **3**A, **4**B, **5**B, **6**A) provides two separate load bearing paths to carry a load in a fall-safe manner, one path carrying the load upon failure of the other.

FIG. **3**A shows that the dual load path structure **83** comprises dual wing skin plates **104** and a rotation joint **84**. The rotation joint **84** (see also FIGS. **4**A, **5**A, **6**A) is preferably coupled between the dual wing skin plates **104** (see also FIGS. **4**B, **5**B, **7**A). The dual wing skin plates **104** (see FIGS. **4**B, **5**B, **7**A) preferably comprise wing skins **106** (see FIGS. **3**A, **4**B, **5**B, **7**A), such as upper wing skin **106***a* (see FIGS. **3**A, **4**B, **5**B, **7**A) and lower wing skin **106***b* (see FIGS. **3**A, **4**B, **5**B, **7**A). Each wing skin **106** (see FIGS. **3**A, **4**B, **5**B, **7**A) preferably has a plate portion **108** (see FIGS. **3**A, **4**B, **5**B) attached to the wing skin **106** (see FIGS. **3**A, **4**B, **5**B). The plate portion **108** (see FIGS. **3**A, **4**B, **5**B) is preferably a titanium plate portion **108***a* (see FIGS. **3**A, **4**B, **5**B). However, another suitably strong metal or hard material may be used for the plate portion.

The upper and lower wing skins **106***a*, **106***b* may be mechanically attached or bonded to wing members **70** (see FIGS. **3**A, **4**A, **5**A, **6**A), such as front wing spar **70***a* (see FIGS. **3**A, **4**A, **5**A, **6**A) and rear wing spar **70***b* (see FIGS. **3**A, **4**A, **5**A, **6**A), and to wing ribs **68** (see FIGS. **3**A, **4**A, **5**F), such as fixed wing rib **68***a* (see FIG. **5**F), to improve the strength and stability of the wing skins **106**.

As further shown in FIG. **3**A, the rotation joint **84** comprises dual rotation elements **86** and a dual rotation pin element **88**. The rotation joint **84** (see FIGS. **3**A, **4**A, **5**A, **6**A) is preferably configured to rotationally couple the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) to the fixed wing portion **78** (see FIGS. **3**A, **4**A, **5**A, **6**A). The rotation joint **84** (see FIGS. **3**A, **4**A, **5**A, **6**A) preferably comprises a dual rotation pin element **88** (see FIGS. **3**A, **4**A, **5**A, **6**A) having a center rotation axis **90** (see FIGS. **3**A, **4**B, **5**B, **6**A) and dual rotation elements **86** (see FIGS. **3**A, **4**A, **5**A, **6**A) configured to rotate about the center rotation axis **90** (see FIGS. **3**A, **4**B, **5**B, **6**A).

The dual rotation pin element **88** (see FIGS. **3**A, **4**A, **5**A, **6**A) preferably comprises, for example but without limitation, one of a disc pin **88***a* (see FIGS. **3**A, **4**A), a pivot pin **88***b* (see FIGS. **3**A, **5**A), a plate pin **88***c* (see FIGS. **3**A, **6**A), or another suitable rotation or pivot pin or element.

The dual rotation elements **86** (see FIGS. **3**A, **4**A, **5**A, **6**A) preferably comprise, for example but without limitation, one of lug elements such as first lug element **86***a* (see FIGS. **3**A, **4**A) and second lug element **86***b* (see FIGS. **3**A, **4**A), rotation fitting elements **86***c* (see FIGS. **3**A, **5**A), rotation plate elements **86***d* (see FIGS. **3**A, **6**A), or another suitable rotation element.

The dual load path structure **83** (see FIGS. **3**A, **4**B, **5**B, **6**A) may further comprise dual channel segments **94** (see FIGS. **4**B-**4**C) coupled between the dual wing skin plates **104** (see FIGS. **4**B-**4**C). As shown in FIGS. **4**B-**4**C, the dual channel segments **94** may comprise first dual channel segment **94***a* and second dual channel segment **94***b*. The dual load path structure **83** (see FIG. **3**A) may further comprise additional suitable redundant structures.

As shown in FIG. **3**A, the swing wing tip system **80** may further comprise a navigation element **102**. The navigation element **102** may comprise a retractable navigation light **102***a* (see also FIG. **4**D) or another suitable navigation or positioning element to facilitate navigation and guidance of the air vehicle **10** (see FIG. **1**) such as on an airport runway or taxiway.

As shown in FIGS. **3**A-**3**B, the swing wing tip system **80** (see also FIGS. **4**A, **5**A, **6**A) further comprises the actuator assembly **98** (see also FIGS. **4**A, **5**A, **6**A) operatively coupled to the rotation joint **84** (see also FIGS. **4**A, **5**A, **6**A) to actuate the rotation joint **84** (see also FIGS. **4**A, **5**A, **6**A). This enables rotation of the unfixed wing tip portion **76** (see also FIGS. **4**A, **5**A, **6**A) with respect to the fixed wing portion **78** (see also FIGS. **4**A, **5**A, **6**A) about the center rotation axis **90** (see also FIGS. **4**B, **5**B, **6**A) at a selected operation condition **131** (see FIG. **3**A). The selected operation condition **131** (see FIG. **3**A) may provide a position of the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) comprising one of an unfolded flight position **132** (see FIGS. **4**A, **5**A, **6**A), a rotation position **162** (see FIG. **3**A) of an aft folded ground position **136** (see FIGS. **4**E, **5**F, **6**C), a rotation position **162** of a forward folded flight position **134** (see FIG. **4**D), or another suitable selected operation condition **131**.

Increasing the wingspan **21** (see FIG. **1**) by using the rotation joint **84** (see FIGS. **4**A, **5**A, **6**A) may provide structural integrity whether the unfixed wing tip portion **76** (see FIGS. **4**A, **5**A, **6**A) of the wing **18** (see FIGS. **4**A, **5**A, **6**A) is in the unfolded flight position **132** (see FIGS. **4**A, **5**A, **6**A) and optimized for high speed, or is in the aft folded ground position **136** (see FIGS. **4**E, **5**F) during taxi and runway travel or during gate parking maneuvers. In one embodiment, as shown in FIG. **4**D and discussed in further detail below, the unfixed wing tip portion **76** of the wing **18** may also rotate or fold forward in a forward folded flight position **134**, such as forward folded take-off and climb position **134***a*, which is a position optimized for low speed flight conditions.

The unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) of the wing **18** (see FIGS. **3**A, **4**A, **5**A, **6**A) may be deployed by the rotation joint **84** (see FIGS. **3**A, **4**A, **5**A, **6**A) from the fixed wing portion **78** (see FIGS. **3**A, **4**A, **5**A, **6**A) through a plurality of positions. The positions may include positioning the unfixed wing tip portion **76** (see FIGS. **4**A, **5**A, **6**A) at the unfolded flight position **132** (see FIGS. **4**A, **5**A, **6**A), which is preferably extended and at high speed, and may move through intermediate positions to the rotated or deployed position. The rotated or deployed position may comprise positioning the unfixed wing tip portion **76** (see FIGS. **4**A, **5**A, **6**A) at, for example but without limitation, the forward folded flight position **134** (see FIG. **4**D) at low speed; the aft folded ground position **136** (see FIGS. **4**E, **5**F) at low speed on airport runways and taxiways and during gate parking maneuvers; or other deployed positions.

As shown in FIG. **3**B, the actuator assembly **98** may comprise, for example but without limitation, one of a rotary electric actuator assembly **98***a*, a linear hydraulic actuator assembly **98***b*, a ball screw actuator assembly **98***c*, or another suitable actuator assembly. Preferably, as shown in FIG. **3**B, the actuator assembly **98** comprises an actuator element **100** and a locking element **118**. As shown in FIG. **3**B, the actuator element **100** may comprise, for example but without limitation, a rotary electric actuator **100***a*, a linear hydraulic actuator **100***b*, a ball screw actuator **100***c*, or another suitable actuator.

As further shown in FIG. **3**B, the locking element **118** may comprise, for example but without limitation, a rack and pinion element **118***a*, a latch hydraulic pin locking element **118***b*, a ball screw locking element **118***c*, or another suitable locking element. The locking element **118** (see FIG. **3**B) is preferably configured to lock the unfixed wing tip portion **76** (see FIG. **3**A) in a rotation position **162** (see FIG. **3**A) relative to the fixed wing portion **78** (see FIG. **3**A) when the actuator element **100** (see FIG. **3**B) actuates the rotation joint **84** (see FIG. **3**A). In a rotation position **162** (see FIG. **3**A), such as the forward folded flight position **134** (see FIG. **4**D) or the aft folded ground position **136** (see FIG. **4**E), the locking element **118** (see FIGS. **4**D, **4**E) may be coupled to the rotation joint **84** (see FIGS. **4**D, **4**E) to secure the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) in place.

The actuator element **100** (see FIGS. **3**A, **4**A, **5**A, **6**A) is preferably configured to produce a rotating motion in response to an actuation command to actuate the rotation joint **84** (see FIGS. **3**A, **4**A, **5**A, **6**A) for rotating the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) with respect to the fixed wing portion **78** (see FIGS. **3**A, **4**A, **5**A, **6**A) about the center rotation axis **90** (see FIGS. **3**A, **4**B, **5**B, **6**A).

As shown in FIG. **3**A, the swing wing tip system **80** further comprises a controller system **150** operatively coupled to the actuator assembly **98** to control the actuator assembly **98** to actuate the rotation joint **84** and rotation of the unfixed wing tip portion **76** according to various operation conditions **131**. In operation, the controller system **150** (see FIGS. **3**A-**3**B) may control the rotation joint **84** (see FIG. **3**A) by sending an actuation command from the actuator element **100** (see FIG. **3**B) to the rotation joint **84** (see FIG. **3**A), thereby swinging/rotating the unfixed wing tip portion **76** (see FIG. **3**A) of the swing wing tip assembly **82** (see FIG. **3**A) in response to the actuation command.

The operation conditions **131** (see FIG. **3**B) may comprise, for example but without limitation, flight conditions, ground operations, or other conditions. The flight conditions may comprise, for example but without limitation, take-off, cruise, approach, landing, or other flight conditions. The ground operations may comprise, for example but without limitation, air breaking after landing, taxing, parking, or other ground operations. The controller system **150** (see FIG. **3**B) may be coupled directly to the rotation joint **84** (see FIG. **3**A) via connection elements such as wires (not shown), or the controller system **150** (see FIG. **3**B) may be coupled wirelessly to and located remotely from the rotation joint **84** (see FIG. **3**A).

As shown in FIG. **3**B, the controller system **150** may comprise, for example but without limitation, a power source **152**, a processor device **154**, a data storage device **156**, and software **158**. The controller system **150** (see FIG. **3**B) may be implemented as, for example but without limitation, a part of an aircraft system, a subsystem processor comprising hardware and/or software for the controller system **150**, a central aircraft processor, or another suitable processor.

The processor device **154** (see FIG. **3**B) may comprise, for example but without limitation, a computer **154***a* (see FIG. **3**B), a microprocessor, a digital signal processor, or another suitable processor device. The processor device **154** (see FIG. **3**B) preferably has memory to store and provide data to the controller system **150** (see FIG. **3**B). Data such as flight configuration data, operation conditions **131** (see FIG. **3**B), rotation position **162** (see FIG. **3**A) of the unfixed wing tip portion **76** (see FIG. **3**A), or other data may be stored in the data storage device **156** (see FIG. **3**B). The data storage device **156** (see FIG. **3**B) may comprise hard disks, optical disks, random access storage devices, or other suitable known data storage devices.

FIG. **4**A is an illustration of a cutaway top plan view of wing **18**, such as in the form of swing wing **18***a*, having wing tip **20**, such as in the form of swing wing tip **20***a*. More specifically, FIG. **4**A is a top plan view, with wing skin cutaway, of selected interior components of swing wing tip system **80** depicted in accordance with an illustrative embodiment.

As shown in FIG. **4**A, the wing **18** is in an unfolded flight position **132**, such as an unfolded cruise position **132***a*, and has a leading edge **22***a* and a trailing edge **22***b*. In the unfolded flight position **132**, such as in the unfolded cruise position **132***a*, the wing **18** is preferably optimized for high speed performance. As further shown in FIG. **4**A, the wing **18** has an embodiment of the swing wing tip system **80**, such as swing wing tip system **80***a*, and an embodiment of the swing wing tip assembly **82**, such as swing wing tip assembly **82***a*, according to the disclosure.

As shown in FIG. **4**A, the swing wing tip assembly **82**, such as swing wing tip assembly **82***a*, comprises the unfixed wing tip portion **76** movably connected to the fixed wing portion **78** via the rotation joint **84** and separated at hinge line **74**. The unfixed wing tip portion **76** may be maintained in line with the fixed wing portion **78** in the unfolded flight position **132** and without rotation during the high speed flight condition.

The unfixed wing tip portion **76** (see FIG. **4**A) may include one or more wing tip members **71** (see FIG. **4**A), such as one or more wing tip spars **71***a* (see FIG. **4**A). The fixed wing portion **78** (see FIG. **4**A) may comprise a wing box **66** (see FIG. **4**A) extending from an inboard to outboard direction and having wing members **70** (see FIG. **4**A), such as front wing spar **70***a* and rear wing spar **70***b* (see FIG. **4**A), one or more wing ribs **68** (see FIG. **4**A), a slat **24** (see FIG. **4**A), an aileron **26** (see FIG. **4**A), or other suitable structures.

In this exemplary embodiment of the swing wing tip assembly **82** shown in FIG. **4**A, the rotation joint **84**, such as in the form of rotation joint **84***a*, comprises a dual rotation pin element **88**, in the form of a disc pin **88***a*, having a center rotation axis **90**, and comprises dual rotation elements **86**, such as in the form of first lug element **86***a* and second lug element **86***b*. The first lug element **86***a* and the second lug element **86***b* are configured to rotate about the center rotation axis **90**.

In this exemplary embodiment of the swing wing tip system **80** shown in FIG. **4**A, the actuator assembly **98** comprises a rotary electric actuator assembly **98***a* having an actuator element **100** and a locking element **118**. The locking element **118** may comprise a rack and pinion element **118***a* (see FIG. **4**A) to lock the rotation joint **84** (see FIG. **4**A) in place, and in turn, the unfixed wing tip portion **76** (see FIG. **4**A) in place, after the rotation joint **84** (see FIG. **4**A) is actuated by the actuator element **100** (see FIG. **4**A) to rotate. Alternatively, the actuator assembly **98**, actuator element **100** and locking element **118** may comprise other suitable assemblies or elements.

FIG. **4**A further shows a shear load path **72** partially around the perimeter of the rotation joint **84**. In addition, FIG. **4**A shows a navigation element **102** enclosed within the wing **18**. The navigation element **102** (see FIG. **4**A) may be positioned near a hinge line **74** (see FIG. **4**A) between the fixed wing portion **78** (see FIG. **4**A) and the unfixed wing tip portion **76** (see FIG. **4**A). The navigation element **102** (see FIG. **4**A) may be exposed and activated in response to rotation of the unfixed wing tip portion **76** (see FIG. **4**A).

FIG. **4**B is an illustration of a cross-sectional view taken along lines **4**B-**4**B of FIG. **4**A. FIG. **4**B shows that the dual load path structure **83** configured to transfer load from the unfixed wing tip portion **76** to the fixed wing portion **78** at a shear load transfer point **73**. At the shear load transfer point **73** (see FIG. **4**B) of this embodiment of the swing wing tip assembly **82** (see FIG. **4**B), about a 200 (two hundred) degree arc length shear load transfer capability may be directed from the unfixed wing tip portion **76** (see FIG. **4**B) to the fixed wing portion **78** (see FIG. **4**B) at the rotation joint **84** (see FIG. **4**B). However, other suitable arc lengths of shear load transfer capability may also be obtained.

As shown in FIG. **4**B, the dual load path structure **83** comprises dual wing skin plates **104** and the rotation joint **84**. The rotation joint **84** (see FIG. **4**B) is preferably coupled between the dual wing skin plates **104** (see FIG. **4**B). As further shown in FIG. **4**B, the dual wing skin plates **104** preferably comprise wing skins **106**, such as upper wing skin **106***a* and lower wing skin **106***b*. As further shown in FIG. **4**B, each wing skin **106** preferably has a plate portion **108**, such as in the form of a titanium plate portions **108***a*, **108***b*, respectively, attached to the wing skin **106**. However, another suitably strong metal or hard material may be used for the plate portion.

The embodiment of the rotation joint **84** of the swing wing tip assembly **82** shown in FIG. **4**B comprises dual rotation elements **86**, such as in the form of first lug element **86***a* and second lug element **86***b*. As further shown in FIG. **4**B, the rotation joint **84** comprises dual rotation pin element **88**, such as in the form of disc pin **88***a* having the center rotation axis **90**, such as a center vertical rotation axis. A diameter **110** of the dual rotation pin element **88** is shown in FIG. **4**B, and such diameter **110** may be, for example, 15 (fifteen) inches, or another suitable length. As shown in FIG. **4**B, the dual rotation pin element **88** is preferably adjacent the first lug element **86***a* and the second lug element **86***b*. As further shown in FIG. **4**B, dual wing skin plates **104** may be attached to the dual rotation pin element **88** via attachment elements **92**, such as bolts **92***a*. However, other suitable attachment elements **92** or bonding may also be used.

The dual wing skin plates **104** (see FIG. **4**B) may act as upper and lower dual devises with the first lug element **86***a* and second lug element **86***b*. In addition, positioning the dual rotation pin element **88** (see FIG. **4**B) between the dual wing skin plates **104** (see FIG. **4**B), i.e., dual devises, may provide replaceability of the unfixed wing tip portion **76** (see FIG. **4**B) in a manner similar to replaceability of known winglets while still providing substantial torsional stiffness of the rotation joint **84** (see FIG. **4**B). Thus, a minimum maintenance may be performed as compared to winglet or wing configurations that allow no access or no maintenance.

As shown in FIG. **4**B, the dual load path structure **83** may further comprise dual channel segments **94**, such as first channel segment **94***a* and second channel segment **94***b*, coupled between the dual wing skin plates **104**. As further shown in FIG. **4**B, the first channel segment **94***a* and second channel segment **94***b* are shown in a back-to-back configuration and are preferably wing box dual channel segments. As further shown in FIG. **4**B, the first lug element **86***a* and the first channel segment **94***a* form a tongue and groove configuration **96**, and the second lug element **86***b* and the first channel segment **94***a* form another tongue and groove configuration **96**.

FIG. **4**C is an illustration of a cross-sectional view taken along lines **4**C-**4**C of FIG. **4**A. FIG. **4**C shows the shear load transfer point **73** that transfers load from the unfixed wing tip portion **76** to the fixed wing portion **78**. FIG. **4**C further shows the dual wing skin plates **104** comprising wing skins **106**, such as upper wing skin **106***a* and lower wing skin **106***b*. As further shown in FIG. **4**C, each wing skin **106** preferably has a plate portion **108**, such as in the form of titanium plate portions **108***a*, **108***b*, respectively, attached to the wing skin **106**.

FIG. **4**C further shows and the rotation joint **84** comprising dual rotation elements **86** and dual rotation pin element **88** having the center rotation axis **90**, such as a center vertical rotation axis. The diameter **110** of the dual rotation pin element **88** is shown in FIG. **4**C. As further shown in FIG. **4**C, the dual wing skin plates **104** may be attached to the dual rotation pin element **88** via attachment elements **92**, such as bolts **92***a*.

As further shown in FIG. **4**C, the dual channel segments **94** of the wing box **66**, such as first channel segment **94***a* and second channel segment **94***b*, are coupled between the dual wing skin plates **104**. As further shown in FIG. **4**C, the first channel segment **94***a* and the dual rotation element **86** form the tongue and groove configuration **96**.

FIG. **4**D is an illustration of a cutaway top plan view of the wing **18**, such as in the form of swing wing **18***a*, of FIG. **4**A. FIG. **4**D shows forward rotation of the wing tip **20**, such as in the form of swing wing tip **20***a*, from an unfolded flight position **132**, such as an unfolded cruise condition **132***a*, to a forward folded flight position **134**, such as forward folded take-off and climb position **134***a*. In the forward folded flight position **134**, the wing **18** is preferably optimized for low speed performance.

Additional wingspan length **112** (see FIG. **4**D) is shown at the unfixed wing tip portion **76**. Such additional wingspan length **112** may be eight (8) feet or more to enhance take-off and climb performance when the unfixed wing tip portion **76** is folded or swept forward thirty (30) degrees at take-off.

As shown in FIG. **4**D, the wing **18** has an embodiment of the swing wing tip system **80**, such as swing wing tip system **80***a*, and an embodiment of the swing wing tip assembly **82**. As further shown in FIG. **4**D, the wing **18** has a leading edge **22***a*, a trailing edge **22***b*, unfixed wing tip portion **76** having one or more wing tip members **71**, such as one or more wing tip spars **71***a*, fixed wing portion **78** having wing box **66**, wing members **70**, such as front wing spar **70***a* and rear wing spar **70***b*, one or more wing ribs **68**, slat **24**, and aileron **26**.

As shown in FIG. **4**D, the hinge line **74** is separated between the unfixed wing tip portion **76** and the fixed wing portion **78**, and the dual rotation elements **86**, such as in the form of first lug element **86***a* and second lug element **86***b*, of the rotation joint **84** are rotated forward about the dual rotation pin element **88**, in the form of a disc pin **88***a*. Attachment elements **92** (see FIG. **4**D) are shown attached to the dual rotation pin element **88** (see FIG. **4**D).

FIG. **4**D further shows actuator assembly **98** with actuator element **100** and locking element **118**, and shows navigation element **102**, such as in the form of retractable navigation light **102***a*. FIG. **4**D further shows shear load path **72**.

FIG. **4**E is an illustration of a cutaway top plan view of the wing **18**, such as in the form of swing wing **18***a*, of FIG. **4**A. FIG. **4**E shows the wing tip **20**, such as in the form of swing wing tip **20***a*, in an aft folded ground position **136**, such as an aft folded taxiing and runway ground position **136***a*. In the aft folded ground position **136**, the wing **18** is preferably optimized for low speed performance, and the unfixed wing tip portion **76** may be rotated approximately 35 (thirty-five) degrees in an aft direction.

As shown in FIG. **4**E, the wing **18** has an embodiment of the swing wing tip system **80**, such as swing wing tip system **80***a*, and an embodiment of the swing wing tip assembly **82**. As further shown in FIG. **4**E, the wing **18** has leading edge **22***a*, trailing edge **22***b*, unfixed wing tip portion **76** having one or more wing tip members **71**, such as one or more wing tip spars **71***a*, fixed wing portion **78** having wing box **66**, wing members **70**, such as front wing spar **70***a* and rear wing spar **70***b*, one or more wing ribs **68**, slat **24**, and aileron **26**.

As shown in FIG. **4**E, the hinge line **74** is separated between the unfixed wing tip portion **76** and the fixed wing portion **78**, and the dual rotation elements **86**, such as in the form of first lug element **86***a* and second lug element **86***b*, of the rotation joint **84** are rotated aft about the dual rotation pin element **88**, such as in the form of a disc pin **88***a*.

FIG. **4**E further shows actuator assembly **98**, such as in the form of rotary electric actuator assembly **98***a*, with actuator element **100** and locking element **118**. FIG. **4**E further shows navigation element **102**, such as in the form of retractable navigation light **102***a*, and shear load path **72**.

FIG. **5**A is an illustration of a cutaway top plan view of a wing **18**, such as swing wing **18***b*, having wing tip **20**, such as in the form of swing wing tip **20***b*. More specifically, FIG. **5**A is a top plan view, with wing skin cutaway, of selected interior components of swing wing tip system **80** depicted in accordance with an illustrative embodiment.

As shown in FIG. **5**A, the wing **18** is in an unfolded flight position **132**, such as an unfolded cruise position **132***b*, and has a leading edge **22***a* and a trailing edge **22***b*. In the unfolded flight position **132**, such as in the unfolded cruise position **132***b*, the wing **18** is preferably optimized for high speed performance. As further shown in FIG. **5**A, the wing **18** has an embodiment of the swing wing tip system **80**, such as swing wing tip system **80***b*, and an embodiment of the swing wing tip assembly **82**, such as swing wing tip assembly **82***b*, according to the disclosure.

As shown in FIG. **5**A, the swing wing tip assembly **82**, such as swing wing tip assembly **82***b*, comprises the unfixed wing tip portion **76** movably connected to the fixed wing portion **78** via the rotation joint **84** and separated at hinge line **74**. The unfixed wing tip portion **76** may be maintained in line with the fixed wing portion **78** in the unfolded flight position **132** and without rotation during the high speed flight condition.

The unfixed wing tip portion **76** (see FIG. **5**A) may include one or more wing tip members **71** (see FIG. **5**A), such as one or more wing tip spars **71***a* (see FIG. **5**A). The fixed wing portion **78** (see FIG. **5**A) may comprise a wing box **66** (see FIG. **5**A) extending from an inboard to outboard direction and having wing members **70** (see FIG. **5**A), such as front wing spar **70***a* and rear wing spar **70***b* (see FIG. **5**A), one or more wing ribs **68** (see FIG. **5**A), such as one or more fixed wing ribs **68***a* (see FIG. **5**A), slat **24** (see FIG. **5**A), aileron **26** (see FIG. **5**A), or other suitable structures.

In this exemplary embodiment of the swing wing tip assembly **82** shown in FIG. **5**A, the rotation joint **84**, such as in the form of rotation joint **84***b*, comprises a dual rotation pin element **88**, in the form of pivot pin **88***b*, having the center rotation axis **90**. As further shown in FIG. **5**A, the rotation joint **84** comprises dual rotation element **86**, such as in the form of rotation fitting element **86***c*. The rotation fitting element **86***c* (see FIG. **5**A) is configured to rotate about the pivot pin **88***b* and the center rotation axis **90** (see FIG. **5**A). Further, as shown in FIG. **5**A, the rotation fitting element **86***c* rotates or pivots between and along tracks **116**. A tip portion **87** (see FIG. **5**E) of rotation fitting element **86***c* (see FIG. **5**A) preferably rotates along a curved portion of track **116** (see FIG. **5**A) adjacent wing rib **68** (see FIG. **5**A).

In this exemplary embodiment of the swing wing tip system **80** shown in FIG. **5**A, the actuator assembly **98** comprises a linear hydraulic actuator assembly **98***b* having an actuator element **100** and locking elements **118**. The locking elements **118** may be in the form of a latch hydraulic pin locking element **118***b* (see FIG. **5**A) to lock the rotation joint **84** (see FIG. **5**A) in place, and in turn, the unfixed wing tip portion **76** (see FIG. **5**A) in place, after the rotation joint **84** (see FIG. **5**A) is actuated by the actuator element **100** (see FIG. **5**A) to rotate. Alternatively, the actuator assembly **98**, actuator element **100**, and locking element **118** may comprise other suitable assemblies or elements.

FIG. **5**A further shows a navigation element **102** enclosed within the wing **18**. The navigation element **102** (see FIG. **5**A) may be positioned near the hinge line **74** (see FIG. **5**A) between the fixed wing portion **78** (see FIG. **5**A) and the unfixed wing tip portion **76** (see FIG. **5**A). The navigation element **102** (see FIG. **5**A) may be exposed and activated in response to rotation of the unfixed wing tip portion **76** (see FIG. **5**A).

In this exemplary embodiment of the swing wing tip system **80** shown in FIG. **5**A, the wing **18** further comprises a moving panel **120** positioned near the trailing edge **22***b* of wing **18**, such as near the unfixed wing tip portion **76**. The moving panel **120** (see FIG. **5**A) is preferably configured to move before the unfixed wing tip portion **76** (see FIG. **5**A) is rotated. The moving panel **120** (see FIG. **5**A) may comprise, for example but without limitation, a folding door **120***a* (see FIG. **5**A) in a folded up configuration **140** (see FIG. **5**A) or other suitable movable panel or surface configuration.

When the unfixed wing tip portion **76** (see FIG. **5**A) is unfolded and not rotated, the moving panel **120** is preferably in the folded up configuration **140** (see FIG. **5**A). The moving panel **120** (see FIG. **5**A) may drop down or fold via a panel actuator mechanism **123** (see FIG. **5**A), or another suitable actuator or sliding mechanism. As shown in FIG. **5**A, the moving panel **120** is preferably designed to fold or rotate around a hinge line **122** and is designed to drop below the trailing edge **22***b* of the wing **18**, such as near the unfixed wing tip portion **76**, before the unfixed wing tip portion **76** is rotated.

FIG. **5**B is an illustration of a cross-sectional view taken along lines **5**B-**5**B of FIG. **5**A. FIG. **5**B shows that the dual load path structure **83** configured to transfer load from the unfixed wing tip portions **76** to the fixed wing portions **78**. As shown in FIG. **4**B, the dual load path structure **83** comprises dual wing skin plates **104** and the rotation joint **84**. The rotation joint **84** (see FIG. **5**B) is preferably coupled between the dual wing skin plates **104** (see FIG. **5**B). As further shown in FIG. **5**B, the dual wing skin plates **104** preferably comprise wing skins **106**, such as upper wing skin **106***a* and lower wing skin **106***b*. As further shown in FIG. **5**B, each wing skin **106** preferably has a plate portion **108**, such as in the form of a titanium plate portion **108***a*, **108***b*, respectively, attached to the wing skin **106**. However, another suitably strong metal or hard material may be used for the plate portion.

The embodiment of the rotation joint **84** of the swing wing tip assembly **82** shown in FIG. **5**B comprises dual rotation elements **86**, such as in the form of rotation fitting element **86***c*, and dual rotation pin element **88** in the form of pivot pin **88***b* (see FIG. **3**A) having the center rotation axis **90** such as a center vertical rotation axis. A diameter **124** of the dual rotation pin element **88**, such as pivot pin **88***b*, is shown in FIG. **5**B, and such diameter **124** may be, for example, 20 (twenty) inches, or another suitable length. As shown in FIG. **5**B, the dual rotation pin element **88** is adjacent each of wing tip spars **71***a*, **71***b*. As further shown in FIG. **5**B, the dual rotation elements **86**, such as in the form of rotation fitting element **86***c*, are adjacent tracks **116**, and tracks **116** are adjacent front wing spar **70***a* and rear wing spar **70***b*, respectively.

FIG. **5**C is an illustration of a close-up view of circle **5**C of FIG. **5**B. As shown in FIG. **5**C, the rotation joint **84** comprises dual rotation pin element **88**, such as pivot pin **88***b*, and dual rotation elements **86**, such as in the form of rotation fitting element **86***c*. As shown in FIG. **5**C, the dual rotation pin element **88** is shown adjacent to wing tip member **71**, such as in the form of wing tip spar **71***a*. As further shown in FIG. **5**C, wing tip member **71** is shown adjacent rotation fitting element **86***c*. As further shown in FIG. **5**C, rotation fitting element **86***c* is shown adjacent track **116**. As further shown in FIG. **5**C, track **116** is shown adjacent wing member **70**, such as rear wing spar **70***b* of wing box **66**.

FIG. **5**C further shows the dual rotation pin element **88** and the track **116** attached to wing skins **106**, such as upper wing skin **106***a* and lower wing skin **106***b*, via attachment elements **92**, such as bolts **92***a*. However, other suitable attachment elements or bonding may also be used. FIG. **5**C further shows approximate distance indicated by arrows **126** between rotation fitting element **86***c* and track **116**, which, for example, may be 5 (five) inches or another suitable distance.

FIG. **5**D is an illustration of a close-up cross-sectional view taken along lines **5**D-**5**D of FIG. **5**A. As shown in FIG. **5**D, dual rotation elements **86**, such as in the form of rotation fitting element **86***c*, is adjacent or near track **116**, and is positioned between wing skins **106** which are attached to track **116** via attachment elements **92**, such as bolts **92***a*, or other suitable attachment elements. FIG. **5**D further shows approximate distance indicated by arrows **128** along track **116** from rotation fitting element **86***c*, which, for example, may be 5 (five) inches or another suitable distance.

FIG. **5**E is an illustration of a close-up cross-sectional view taken along lines **5**E-**5**E of FIG. **5**A. As shown in FIG. **5**E, the locking element **118**, such as in the form of latch hydraulic pin locking element **118***b*, is inserted through and attaches together wing rib **68**, such as in the form of fixed wing fib **68***a*, track **116**, and the tip portion **87** of the rotation fitting element **86***c*. FIG. **5**E further shows the wing rib **68** and the track **116** attached via attachment elements **92**, such as bolts **92***a*, or another suitable attachment element.

FIG. **5**F is an illustration of a cutaway top plan view of the wing **18**, such as swing wing **18***b*, of FIG. **5**A having wing tip **20**, such as swing wing tip **20***a*. The wing **18** (see FIG. **5**F) has a leading edge **22***a* (see FIG. **5**F) and a trailing edge **22***b* (see FIG. **5**F). As shown in FIG. **5**F, the unfixed wing tip portion **76** is in an aft folded ground position **136**, such as aft folded taxiing and runway ground position **136***b*. As further shown in FIG. **5**F, the wing **18** has an embodiment of the swing wing tip system **80**, such as swing wing tip system **80***b*, and an embodiment of the swing wing tip assembly **82**, such as swing wing tip assembly **82***b*, according to the disclosure.

As shown in FIG. **5**F, the swing wing tip assembly **82**, such as swing wing tip assembly **82***b*, comprises the unfixed wing tip portion **76** movably connected to the fixed wing portion **78** via the rotation joint **84** (see FIG. **5**A) and separated at hinge line **74** (see FIG. **5**A). The unfixed wing tip portion **76** (see FIG. **5**F) may include one or more wing tip members **71** (see FIG. **5**F), such as one or more wing tip spars **71***a* (see FIG. **5**F). The fixed wing portion **78** (see FIG. **5**F) may comprise a wing box **66** (see FIG. **5**F) extending from an inboard to outboard direction and having wing members **70** (see FIG. **5**F), such as front wing spar **70***a* and rear wing spar **70***b* (see FIG. **5**F), one or more wing ribs **68** (see FIG. **5**F), such as one or more fixed wing ribs **68***a* (see FIG. **5**F), slat **24** (see FIG. **5**A), aileron **26** (see FIG. **5**A), or other suitable structures.

In this exemplary embodiment of the swing wing tip assembly **82** shown in FIG. **5**F, the rotation joint **84** (see FIG. **5**A) comprises a dual rotation pin element **88**, such as in the form of pivot pin **88***b*, having the center rotation axis **90**. The rotation joint **84** (see FIG. **5**A) further comprises dual rotation element **86** (see FIG. **5**F), such as in the form of rotation fitting element **86***c* (see FIG. **5**F). The rotation fitting element **86***c* (see FIG. **5**F) is configured to rotate about the pivot pin **88***b* (see FIG. **5**F) and the center rotation axis **90** (see FIG. **5**F). Further, as shown in FIG. **5**F, the rotation fitting element **86***c* rotates or pivots between and along tracks **116**. The tip portion **87** (see FIG. **5**E) of rotation fitting element **86***c* (see FIG. **5**F) preferably rotates along a curved portion of track **116** (see FIG. **5**F) adjacent wing rib **68** (see FIG. **5**F).

In this exemplary embodiment of the swing wing tip system **80** shown in FIG. **5**F, the actuator assembly **98** comprises a linear hydraulic actuator assembly **98***b* having an actuator element **100** and locking elements **118**. The locking elements **118** may be in the form of a latch hydraulic pin locking element **118***b* (see FIG. **5**F) to lock the rotation joint **84** (see FIG. **5**A) in place, and in turn, the unfixed wing tip portion **76** (see FIG. **5**F) in place, after the rotation joint **84** (see FIG. **5**A) is actuated by the actuator element **100** (see FIG. **5**F) to rotate. Alternatively, the actuator assembly **98** (see FIG. **5**F), actuator element **100** (see FIG. **5**F), and locking element **118** (see FIG. **5**F) may comprise other suitable assemblies or elements.

FIG. **5**F further shows a navigation element **102** enclosed within the wing **18**. The navigation element **102** (see FIG. **5**F) may be positioned near the hinge line **74** (see FIG. **5**F) between the fixed wing portion **78** (see FIG. **5**F) and the unfixed wing tip portion **76** (see FIG. **5**F). The navigation element **102** (see FIG. **5**F) may be exposed and activated in response to rotation of the unfixed wing tip portion **76** (see FIG. **5**F).

In this exemplary embodiment of the swing wing tip system **80** shown in FIG. **5**F, the wing **18** further comprises the moving panel **120** positioned near the trailing edge **22***b* of wing **18**, such as near the unfixed wing tip portion **76**. The moving panel **120** (see FIG. **5**F) is preferably configured to move before the unfixed wing tip portion **76** (see FIG. **5**F) is rotated. The moving panel **120** (see FIG. **5**F) may comprise, for example but without limitation, a folding door **120***a* (see FIG. **5**F) in a folded up configuration **140** (see FIG. **5**F) or other suitable movable panel or surface configuration.

When the unfixed wing tip portion **76** (see FIG. **5**F) is unfolded and not rotated, the moving panel **120** is preferably in the folded up configuration **140** (see FIG. **5**F). The moving panel **120** (see FIG. **5**F) may drop down or fold via the panel actuator mechanism **123** (see FIG. **5**F), or another suitable actuator or sliding mechanism. As shown in FIG. **5**F the moving panel **120**, such as in the form of moving door **120***a*, is shown in a folded down position **142**.

FIG. **6**A is an illustration of a cutaway top plan view of a wing **18**, such as swing wing **18***c*, having wing tip **20**, such as in the form of swing wing tip **20***c*. More specifically, FIG. **6**A is a top plan view, with wing skin cutaway, of selected interior components of swing wing tip system **80** depicted in accordance with an illustrative embodiment.

As shown in FIG. **6**A, the wing **18** is in an unfolded flight position **132**, such as an unfolded cruise position **132***c*. In the unfolded flight position **132**, such as in the unfolded cruise position **132***b*, the wing **18** is preferably optimized for high speed performance. As further shown in FIG. **6**A, the wing **18** has yet another embodiment of the swing wing tip system **80**, such as swing wing tip system **80***c*, and yet another embodiment of the swing wing tip assembly **82**, such as swing wing tip assembly **82***c*, according to the disclosure.

As shown in FIG. **6**A, the swing wing tip assembly **82** comprises the unfixed wing tip portion **76** movably connected to the fixed wing portion **78** via the rotation joint **84**, such as in the form of rotation joint **84***c*, and separated at hinge line **74**. The unfixed wing tip portion **76** may be maintained in line with the fixed wing portion **78** in the unfolded flight position **132** and without rotation during the high speed flight condition.

The unfixed wing tip portion **76** (see FIG. **6**A) may include one or more wing tip members **71** (see FIG. **6**A), such as one or more wing tip spars **71***a* (see FIG. **6**A). The fixed wing portion **78** (see FIG. **6**A) may comprise a wing box **66** (see FIG. **6**A) extending from an inboard to outboard direction and having front wing spar **70***a* and rear wing spar **70***b* (see FIG. **6**A), slat **24** (see FIG. **6**A), or other suitable structures.

In this exemplary embodiment of the swing wing tip assembly **82** shown in FIG. **6**A, the rotation joint **84**, such as in the form of rotation joint **84***c*, comprises a dual rotation pin element **88**, in the form of plate pin **88***c*, having the center rotation axis **90**. As further shown in FIG. **6**A, the rotation joint **84** comprises dual rotation elements **86**, such as in the form of rotation plate elements **86***d*. The rotation plate elements **86***d* (see FIG. **6**A) are preferably configured to rotate about the plate pin **88***c* and the center rotation axis **90** (see FIG. **6**A) and to rotate in line with pivot axis **130** (see FIG. **6**A).

In this exemplary embodiment of the swing wing tip system **80** shown in FIG. **6**A, the actuator assembly **98** comprises a linear hydraulic actuator assembly **98***b* having an actuator element **100** and locking element **118**. The locking element **118** may be in the form of a latch hydraulic pin locking element **118***b* (see FIG. **6**A) to lock the rotation joint **84** (see FIG. **6**A) in place, and in turn, the unfixed wing tip portion **76** (see FIG. **6**A) in place, after the rotation joint **84** (see FIG. **6**A) is actuated by the actuator element **100** (see FIG. **6**A) to rotate. Alternatively, the actuator assembly **98**, actuator element **100** and locking element **118** may comprise other suitable assemblies or elements.

FIG. **6**A further shows a navigation element **102** enclosed within the wing **18**. The navigation element **102** (see FIG. **6**A) may be positioned near the hinge line **74** (see FIG. **6**A) between the fixed wing portion **78** (see FIG. **6**A) and the unfixed wing tip portion **76** (see FIG. **6**A). The navigation element **102** (see FIG. **6**A) may be exposed and activated in response to rotation of the unfixed wing tip portion **76** (see FIG. **6**A).

In this exemplary embodiment of the swing wing tip system **80** shown in FIG. **6**A, the wing **18** further comprises a moving panel **120** positioned near the trailing edge **22***b* of wing **18**, such as near the unfixed wing tip portion **76**. The moving panel **120** (see FIG. **6**A) is preferably configured to move before the unfixed wing tip portion **76** (see FIG. **6**A) is rotated. The moving panel **120** (see FIG. **6**A) may comprise, for example but without limitation, a folding door **120***a* (see FIG. **6**A). As shown in FIG. **6**A, the moving panel **120** is preferably designed to fold or rotate around a hinge line **122** and is designed to drop below the trailing edge **22***b* of the wing **18**, such as near the unfixed wing tip portion **76**, before the unfixed wing tip portion **76** is rotated.

FIG. **6**B is an illustration of a cutaway top plan view of the wing **18**, such as swing wing **18***c*, of FIG. **6**A, having wing tip

**20**, such as in the form of swing wing tip **20***c*. As shown in FIG. **6**B, the wing **18** is in an aft folded transition position **138** from an unfolded flight position **132**, such as an unfolded cruise position **132***c*. In the unfolded flight position **132**, such as in the unfolded cruise position **132***c*, the wing **18** is preferably optimized for high speed performance. As further shown in FIG. **6**B, the wing **18** has yet another embodiment of the swing wing tip system **80**, such as swing wing tip system **80***c*, and yet another embodiment of the swing wing tip assembly **82**, such as swing wing tip assembly **82***c*, according to the disclosure.

As shown in FIG. **6**B, the swing wing tip assembly **82** comprises the unfixed wing tip portion **76** movably connected to the fixed wing portion **78** via the rotation joint **84**, such as in the form of rotation joint **84***c*, and separated at hinge line **74**. The unfixed wing tip portion **76** (see FIG. **6**B) may include one or more wing tip members **71** (see FIG. **6**B), such as one or more wing tip spars **71***a* (see FIG. **6**B). The fixed wing portion **78** (see FIG. **6**B) may comprise a wing box **66** (see FIG. **6**B) extending from an inboard to outboard direction and having wing members **70**, such as front wing spar **70***a* and rear wing spar **70***b* (see FIG. **6**A), slat **24** (see FIG. **6**A), or other suitable structures.

In this exemplary embodiment of the swing wing tip system **80** shown in FIG. **6**B, the rotation joint **84**, such as in the form of rotation joint **84***c*, comprises a dual rotation pin element **88**, in the form of plate pin **88***c*, having the center rotation axis **90**. As further shown in FIG. **6**B, the rotation joint **84** comprises dual rotation elements **86**, such as in the form of rotation plate elements **86***d*. The rotation plate elements **86***d* (see FIG. **6**B) are preferably configured to rotate about the plate pin **88***c* and the center rotation axis **90** (see FIG. **6**B) and to rotate in line with pivot axis **130** (see FIG. **6**B).

In this exemplary embodiment of the swing wing tip system **80** shown in FIG. **6**B, the actuator assembly **98** comprises a linear hydraulic actuator assembly **98***b* having an actuator element **100** (see FIG. **6**B) and locking element **118** (see FIG. **6**B). The locking element **118** (see FIG. **6**B) may be in the form of a latch hydraulic pin locking element **118***b* (see FIG. **6**B) to lock the rotation joint **84** (see FIG. **6**B) in place, and in turn, the unfixed wing tip portion **76** (see FIG. **6**B) in place, after the rotation joint **84** (see FIG. **6**A) is actuated by the actuator element **100** (see FIG. **6**B) to rotate. Alternatively, the actuator assembly **98**, actuator element **100** and locking element **118** may comprise other suitable assemblies or elements.

In this exemplary embodiment of the swing wing tip system **80** shown in FIG. **6**B, the wing **18** further comprises a moving panel **120** positioned near the trailing edge **22***b* (see FIG. **6**A) of wing **18**, such as near the unfixed wing tip portion **76**. The moving panel **120** (see FIG. **6**B) is preferably configured to move before the unfixed wing tip portion **76** (see FIG. **6**B) is rotated. The moving panel **120** (see FIG. **6**B) may comprise, for example but without limitation, a folding door **120***a* (see FIG. **6**B).

FIG. **6**C is an illustration of a cutaway top plan view of the wing **18**, such as swing wing **18***c*, of FIG. **6**A, showing aft rotation of the wing **18** from an unfolded flight position **132**, such as unfolded cruise condition **132***c*, to an aft folded ground position **136**, such as aft folded taxiing and runway ground position **136***c*. As further shown in FIG. **6**C, the wing **18** has yet another embodiment of the swing wing tip system **80**, such as swing wing tip system **80***c*, and yet another embodiment of the swing wing tip assembly **82**, such as swing wing tip assembly **82***c*, according to the disclosure.

As shown in FIG. **6**C, the swing wing tip assembly **82** comprises the unfixed wing tip portion **76** movably connected to the fixed wing portion **78** via the rotation joint **84**, such as in the form of rotation joint **84***c*, and separated at hinge line **74**. The unfixed wing tip portion **76** (see FIG. **6**C) may include one or more wing tip members **71** (see FIG. **6**C), such as one or more wing tip spars **71***a* (see FIG. **6**C). The fixed wing portion **78** (see FIG. **6**C) may comprise a wing box **66** (see FIG. **6**C) extending from an inboard to outboard direction and having wing members **70**, such as front wing spar **70***a* and rear wing spar **70***b* (see FIG. **6**A), slat **24** (see FIG. **6**C), or other suitable structures.

In this exemplary embodiment of the swing wing tip assembly **82** shown in FIG. **6**C, the rotation joint **84**, such as in the form of rotation joint **84***c*, comprises a dual rotation pin element **88**, in the form of plate pin **88***c*, having the center rotation axis **90**. As further shown in FIG. **6**C, the rotation joint **84** comprises dual rotation elements **86**, such as in the form of rotation plate elements **86***d*. The rotation plate elements **86***d* (see FIG. **6**C) are preferably configured to rotate about the plate pin **88***c* and the center rotation axis **90** (see FIG. **6**C) and to rotate in line with pivot axis **130** (see FIG. **6**C).

In this exemplary embodiment of the swing wing tip system **80** shown in FIG. **6**C, the actuator assembly **98** comprises a linear hydraulic actuator assembly **98***b* (see FIG. **6**B) having an actuator element **100** and locking element **118**. The locking element **118** may be in the form of a latch hydraulic pin locking element **118***b* (see FIG. **6**A) to lock the rotation joint **84** (see FIG. **6**C) in place, and in turn, the unfixed wing tip portion **76** (see FIG. **6**C) in place, after the rotation joint **84** (see FIG. **6**C) is actuated by the actuator element **100** (see FIG. **6**C) to rotate. Alternatively, the actuator assembly **98**, actuator element **100** and locking element **118** may comprise other suitable assemblies or elements.

FIG. **6**C further shows a navigation element **102** enclosed within the wing **18**. The navigation element **102** (see FIG. **6**C) may be positioned near the hinge line **74** (see FIG. **6**C) between the fixed wing portion **78** (see FIG. **6**C) and the unfixed wing tip portion **76** (see FIG. **6**A). The navigation element **102** (see FIG. **6**C) may be exposed and activated in response to rotation of the unfixed wing tip portion **76** (see FIG. **6**C).

In this exemplary embodiment of the swing wing tip system **80** shown in FIG. **6**C, the wing **18** further comprises a moving panel **120** positioned near the trailing edge **22***b* of wing **18**, such as near the unfixed wing tip portion **76**. The moving panel **120** (see FIG. **6**C) is preferably configured to move before the unfixed wing tip portion **76** (see FIG. **6**C) is rotated. The moving panel **120** (see FIG. **6**C) may comprise, for example but without limitation, a folding door **120***a* (see FIG. **6**C). As shown in FIG. **6**C, the moving panel **120** is preferably designed to fold or rotate around a hinge line **122** and is designed to drop below the trailing edge **22***b* of the wing **18**, such as near the unfixed wing tip portion **76**, before the unfixed wing tip portion **76** is rotated.

FIG. **7**A is an illustration of a cutaway top perspective view of the wing **18**, such as swing wing **18***c*, showing the wing **18** folded aft and showing the dual load path structure **83**. As shown in FIG. **7**A, the wing **18** has swing wing tip system **80**, such as swing wing tip system **80***c*, and has swing wing tip assembly **82**, such as swing wing tip assembly **82***c*.

As shown in FIG. **7**A, the swing wing tip assembly **82** comprises the unfixed wing tip portion **76** movably connected to the fixed wing portion **78** via the rotation joint **84**, such as in the form of rotation joint **84***c*, and separated at hinge line **74**. FIG. **7**A further shows wing box **66**, wing members **70**, such as front wing spar **70**$a$ and rear wing spar **70**$b$, wing tip member **71**, such as wing tip spar **71**$a$, the navigation element **102** positioned at the hinge line **74**, and moving panel **120**, such as folding door **120**$a$, at hinge line **122**.

FIG. **7**A further shows the dual load path structure **83** comprising the dual wing skin plates **104** with the wing skins **106**, such as upper wing skin **106**$a$ and lower wing skin **106**$b$, and each wing skin **106** having plate portion **108**. As further shown in FIG. **7**A, the dual load path structure **83** comprises rotation joint **84**, such as in the form of rotation joint **84**$c$, comprising the dual rotation pin element **88**, such as in the form of plate pin **88**$c$, and the dual rotation elements **86**, such as in the form of rotation plate elements **86**$d$. The rotation plate elements **86**$d$ (see FIG. **7**A) are preferably configured to rotate about the plate pin **88**$c$ (see FIG. **7**A) and to rotate in line with pivot axis **130** (see FIG. **7**A).

In this exemplary embodiment of the swing wing tip system **80** shown in FIG. **7**A, the actuator assembly **98** may comprise a linear hydraulic actuator assembly **98**$b$ having an actuator element **100** and locking element **118**, such as in the form of locking element **118**$b$. The locking element **118** (see FIG. **7**A) may be in the form of a latch hydraulic pin locking element **118**$b$ (see FIG. **7**A). Alternatively, the actuator assembly **98**, actuator element **100** and locking element **118** may comprise other suitable assemblies or elements.

FIG. **7**B is an illustration of a close-up cutaway top perspective view of an embodiment of the rotation joint **84** of FIG. **7**A coupled to a slide plate assembly **144**. As shown in FIG. **7**B, the rotation joint **84** comprises the dual rotation pin element **88**, such as in the form of plate pin **88**$c$, and the dual rotation elements **86**, such as in the form of rotation plate elements **86**$d$ (see FIG. **7**A). As further shown in FIG. **7**B, the dual rotation elements **86**, which are moving parts, are coupled to the slide plate assembly **144**, which are fixed parts. As further shown in FIG. **7**B, the slide plate assembly **144** comprises a first plate portion **146** attached to a second plate portion **148**. The dual rotation elements **86** (see FIG. **7**B) are preferably configured to rotate about the plate pin **88**$c$ (see FIG. **7**B) within the slide plate assembly **144** and in line with pivot axis **130** (see FIG. **7**B).

FIG. **7**B further shows the wing **18**, such as in the form of swing wing **18**$c$, with the swing wing tip system **80**, such as swing wing tip system **80**$c$, and with the swing wing tip assembly **82**, such as swing wing tip assembly **82**$c$. FIG. **7**B further shows the unfixed wing tip portion **76** and the fixed wing portion **78** separated by hinge line **74**, and shows wing box **66**, wing members **70**, such as front wing spar **70**$a$ and rear wing spar **70**$b$, wing tip member **71**, such as wing tip spar **71**$a$, the navigation element **102** positioned at the hinge line **74**, the wing skins **106**, such as upper wing skin **106**$a$ and lower wing skin **106**$b$, the plate portion **108**, and moving panel **120**, such as folding door **120**$a$, at hinge line **122**, in the folded up position **140**. FIG. **7**B further shows the actuator assembly **98**, such as in the form of linear hydraulic actuator assembly **98**$b$, having actuator element **100** and locking element **118**.

FIG. **7**C is an illustration of a close-up top perspective view of the rotation joint **84** of FIG. **7**B showing a cover plate **145** coupled to the slide plate assembly **144**. The cover plate **145** is preferably coupled to and fitted within the top of the second plate portion **148** of the slide plate assembly **144** and is shown positioned over the dual rotation pin element **88** (see FIG. **7**B), such as in the form of plate pin **88**$c$ (see FIG. **7**B). As shown in FIG. **7**C, when the dual rotation elements **86** are coupled to the second plate portion **148** of the slide plate assembly **144**, the tongue and groove configuration **96** is formed. The dual rotation elements **86** (see FIG. **7**C) are preferably configured to rotate within the slide plate assembly **144** (see FIG. **7**C) and in line with pivot axis **130** (see FIG. **7**C).

FIG. **7**C further shows the wing **18**, such as in the form of swing wing **18**$c$, with the swing wing tip system **80**, such as swing wing tip system **80**$c$, the unfixed wing tip portion **76** and the fixed wing portion **78** separated by hinge line **74**, wing members **70**, such as front wing spar **70**$a$ and rear wing spar **70**$b$, wing tip member **71**, navigation element **102**, wing skins **106**, such as upper wing skin **106**$a$ and lower wing skin **106**$b$, plate portion **108**, and moving panel **120**, such as folding door **120**$a$, at hinge line **122**, in the folded up position **140**.

In another embodiment of the disclosure, there is provided an aircraft **11** (see FIGS. **1**, **3**A) having fail-safe load paths **160** (see FIG. **3**A) for one or more wings **18** (see FIGS. **1**, **3**A), such as in the form of swing wings **18**$a$. As shown in FIG. **1**, the aircraft **11** comprises at least one fuselage **12** and one or more wings **18** each having a wing tip **20** with a swing wing tip system **80**. The aircraft **11** (see FIGS. **1**, **3**A) preferably has a wingspan **21** (see FIGS. **1**, **3**A) configured to be reduced or decreased in length to provide a reduced wingspan **21**$a$ (see FIG. **3**A) to allow ground operation of the aircraft **11** (see FIGS. **1**, **3**A) at an airport that prohibits ground operation of aircraft with an expanded wingspan.

The swing wing tip system **80** (see FIGS. **3**A, **4**A, **5**A, **6**A) of the aircraft **11** (see FIG. **1**) preferably comprises the swing wing tip assembly **82** (see FIGS. **3**A, **4**A, **5**A, **6**A), as discussed in detail above. The swing wing tip assembly (see FIGS. **3**A, **4**A, **5**A, **6**A) comprises the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) movably connected to the fixed wing portion **78** (see FIGS. **3**A, **4**A, **5**A, **6**A) of the one or more wings **18** (see FIGS. **3**A, **4**A, **5**A, **6**A) of the aircraft **11** (see FIGS. **1**, **3**A).

The swing wing tip assembly **82** (see FIGS. **3**A, **4**A, **5**A, **6**A) of the aircraft **11** (see FIG. **1**) further comprises the dual load path structure **83** (see FIGS. **3**A, **4**B, **5**B, **6**A) providing fail-safe load paths **160** (see FIG. **3**A) for the one or more wings **18** (see FIGS. **1**, **3**A). The dual load path structure **83** (see FIGS. **3**A, **4**B, **5**B, **6**A) is preferably configured to transfer load from the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) to the fixed wing portion **78** (see FIGS. **3**A, **4**A, **5**A, **6**A).

As discussed above, the dual load path structure **83** (see FIGS. **3**A, **4**B, **5**B, **6**A) comprises dual wing skin plates **104** (see FIGS. **3**A, **4**B, **5**B, **7**A) comprising wing skins **106** (see FIGS. **3**A, **4**B, **5**B, **7**A), such as upper wing skin **106**$a$ (see FIGS. **3**A, **4**B, **5**B, **7**A) and lower wing skin **106**$b$ (see FIGS. **3**A, **4**B, **5**B, **7**A). Each wing skin **106** (see FIGS. **3**A, **4**B, **5**B) has a plate portion **108** (see FIGS. **3**A, **4**B, **5**B) attached to the wing skin **106** (see FIGS. **3**A, **4**B, **5**B). The plate portion **108** (see FIGS. **3**A, **4**B, **5**B) is preferably a titanium plate portion **108**$a$ (see FIGS. **3**A, **4**B, **5**B). However, another suitably strong metal or hard material may be used for the plate portion.

The dual load path structure **83** (see FIGS. **3**A, **4**B, **5**B, **6**A) of the aircraft **11** (see FIG. **1**) preferably further comprises the rotation joint **84** (see FIGS. **3**A, **4**A, **5**A, **6**A) coupled between the dual wing skin plates **104** (see FIGS. **3**A, **4**B, **5**B, **7**A). The rotation joint **84** (see FIGS. **3**A, **4**A, **5**A, **6**A) is preferably configured to rotationally couple the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) to the fixed wing portion **78** (see FIGS. **3**A, **4**A, **5**A, **6**A). The rotation joint **84** (see FIGS. **3**A, **4**A, **5**A, **6**A) preferably comprises the dual rotation pin element **88** (see FIGS. **3**A, **4**A, **5**A, **6**A) having a center rotation axis **90** (see FIGS. **3**A, **4**B, **5**B, **6**A) and dual rotation elements **86** (see FIGS. **3**A, **4**A, **5**A, **6**A) configured to rotate about the center rotation axis **90** (see FIGS. **3**A, **4**B, **5**B, **6**A).

The dual load path structure **83** (see FIGS. **3**A, **4**B, **5**B, **6**A) may further comprise dual channel segments **94** (see FIGS. **4**B-**4**C) coupled between the dual wing skin plates **104** (see FIGS. **4**B-**4**C).

The one or more wings **18** (see FIGS. **1**, **3**A) of the aircraft **11** (see FIG. **1**) further comprises an actuator assembly **98** (see FIGS. **3**A, **4**A, **5**A, **6**A) operatively coupled to the rotation joint **84** (see FIGS. **3**A, **4**A, **5**A, **6**A) to actuate the rotation joint (see FIGS. **3**A, **4**A, **5**A, **6**A), enabling rotation of the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) with respect to the fixed wing portion **78** (see FIGS. **3**A, **4**A, **5**A, **6**A) about the center rotation axis **90** (see FIGS. **3**A, **4**B, **5**B, **6**A) and in line with pivot axis **130** (see FIGS. **6**C, **7**A) at the selected operation condition **131** (see FIG. **3**A). The selected operation condition **131** (see FIG. **3**A) may provide a position of the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) comprising one of an unfolded flight position **132** (see FIGS. **4**A, **5**A, **6**A), an aft folded ground position **136** (see FIGS. **4**E, **5**F, **6**C), a forward folded flight position **134** (see FIG. **4**D), or another suitable selected operation condition.

The one or more wings **18** (see FIGS. **1**, **3**A) of the aircraft **11** (see FIG. **1**) further comprises a controller system **150** (see FIG. **3**A) operatively coupled to the actuator assembly **98** (see FIGS. **3**A, **4**A, **5**A, **6**A) to control actuation of the rotation joint **84** (see FIGS. **3**A, **4**A, **5**A, **6**A) and rotation of the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A). The one or more wings **18** (see FIGS. **1**, **3**A) further comprises a navigation element **102** (see FIGS. **4**A, **5**A, **6**A) positioned near a hinge line **74** (see FIGS. **4**A, **5**A, **6**A) between the fixed wing portion **78** (see FIGS. **3**A, **4**A, **5**A, **6**A) and the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) and operable to be exposed and activated in response to rotation of the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A).

The swing wing tip assembly **82** (see FIGS. **3**A, **4**A, **5**A, **6**A) of the aircraft **11** (see FIG. **1**) further comprises a moving panel **120** (see FIGS. **5**A, **6**A) positioned near a trailing edge **22***b* (see FIGS. **5**A, **6**A) of the unfixed wing tip portion **76** (see FIGS. **5**A, **6**A) and configured to move before the unfixed wing tip portion **76** (see FIGS. **5**A, **6**A) is rotated.

In another embodiment of the disclosure, there is provided a method **200** (see FIG. **8**) for providing fail-safe load paths **160** (see FIG. **3**A) for a wing **18** (see FIGS. **1**, **3**A) of an air vehicle **10** (see FIGS. **1**, **3**A), such as an aircraft **11** (see FIGS. **1**, **3**A). FIG. **8** is an illustration of a flow diagram of an exemplary embodiment of the method **200** of the disclosure.

The method **200** may include steps listed below. The steps listed for method **200** may be performed in an order other than that presented. Some steps may be performed simultaneously. Some steps may be optional or omitted. Steps other than those listed may be added. Performance of some steps, or ordering of steps, may be dependent upon a beginning position of the wing, such as a flight position or a folded position, or being in transition between positions.

As shown in FIG. **8**, the method **200** comprises step **202** of operatively coupling a swing wing tip assembly **82** (see FIGS. **3**A, **4**A, **5**A, **6**A) to the wing **18** (see FIGS. **1**, **3**A, **4**A, **5**A, **6**A), such as in the form of swing wing **18***a*, **18***b*, **18***c* (see FIG. **3**A), of the air vehicle **10** (see FIGS. **1**, **3**A). As discussed in detail above, the swing wing tip assembly **82** (see FIGS. **3**A, **4**A, **5**A, **6**A) comprises the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) movably connected to the fixed wing portion **78** (see FIGS. **3**A, **4**A, **5**A, **6**A) of the wing **18** (see FIGS. **3**A, **4**A, **5**A, **6**A).

As discussed in detail above, the swing wing tip assembly **82** (see FIGS. **3**A, **4**A, **5**A, **6**A) further comprises the dual load path structure **83** (see FIGS. **3**A, **4**B, **5**B, **6**A). The dual



load path structure **83** (see FIGS. **3**A, **4**B, **5**B, **6**A) preferably comprises dual wing skin plates **104** (see FIGS. **3**A, **4**B, **5**B, **7**A) and the rotation joint **84** (see FIGS. **3**A, **4**A, **5**A, **6**A) coupled between the dual wing skin plates **104** (see FIGS. **3**A, **4**B, **5**B, **7**A). The rotation joint **84** (see FIGS. **3**A, **4**A, **5**A, **6**A) preferably comprises the dual rotation pin element **88** (see FIGS. **3**A, **4**A, **5**A, **6**A) having a center rotation axis **90** (see FIGS. **3**A, **4**B, **5**B, **6**A) and dual rotation elements **86** (see FIGS. **3**A, **4**A, **5**A, **6**A) configured to rotate about the center rotation axis **90** (see FIGS. **3**A, **4**B, **5**B, **6**A).

As shown in FIG. **8**, the method **200** further comprises step **204** of operatively coupling an actuator assembly **98** (see FIGS. **3**A, **4**A, **5**A, **6**A) to the rotation joint **84** (see FIGS. **3**A, **4**A, **5**A, **6**A). As shown in FIG. **8**, the method **200** further comprises step **206** of operatively coupling a controller system **150** (see FIG. **3**A) to the actuator assembly **98** (see FIGS. **3**A, **4**A, **5**A, **6**A) to control the actuator assembly **98** (see FIGS. **3**A, **4**A, **5**A, **6**A) to actuate the rotation joint **84** (see FIGS. **3**A, **4**A, **5**A, **6**A).

As shown in FIG. **8**, the method **200** further comprises step **208** of transferring load from the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) to the fixed wing portion **78** (see FIGS. **3**A, **4**A, **5**A, **6**A) via the dual load path structure **83** (see FIGS. **3**A, **4**B, **5**B, **6**A). This provides fail-safe load paths **160** (see FIG. **3**A) for the wing **18** (see FIGS. **1**, **3**A, **4**A, **5**A, **6**A) of the air vehicle **10** (see FIGS. **1**, **3**A).

As shown in FIG. **8**, the method **200** further comprises optional step **210** of rotating the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) with respect to the fixed wing portion **78** (see FIGS. **3**A, **4**A, **5**A, **6**A) about the center rotation axis **90** (see FIGS. **3**A, **4**B, **5**B, **6**A) at a selected operation condition **131** (see FIG. **3**A). The step **210** of rotating the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) with respect to the fixed wing portion **78** (see FIGS. **3**A, **4**A, **5**A, **6**A) at the selected operation condition **131** (see FIG. **3**A) may further comprise rotating the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) to provide an aft folded ground position **136** (see FIGS. **4**E, **5**F, **6**C). Further, the step **210** of rotating the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) with respect to the fixed wing portion **78** (see FIGS. **3**A, **4**A, **5**A, **6**A) at the selected operation condition **131** (see FIG. **3**A) may further comprise rotating the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A, **5**A, **6**A) to provide a forward folded flight position **134** (see FIG. **4**D).

As shown in FIG. **8**, the method **200** further comprises optional step **212** of operatively coupling a navigation element **102** (see FIGS. **4**A, **5**A, **6**A) near the hinge line **74** (see FIGS. **4**A, **5**A, **6**A) between the fixed wing portion **78** (see FIGS. **4**A, **5**A, **6**A) and the unfixed wing tip portion **76** (see FIGS. **4**A, **5**A, **6**A). The navigation element **102** (see FIGS. **4**A, **5**A, **6**A) may be exposed and activated in response to rotation of the unfixed wing tip portion **76** (see FIGS. **4**A, **5**A, **6**A).

As shown in FIG. **8**, the method **200** further comprises optional step **214** of moving a moving panel **120** (see FIGS. **5**A, **6**A) positioned near the trailing edge **22***b* (see FIGS. **5**A, **6**A) of the unfixed wing tip portion **76** (see FIGS. **5**A, **6**A) before rotating the unfixed wing tip portion **76** (see FIGS. **5**A, **6**A). As shown in FIG. **8**, the method **200** further comprises optional step **216** of maintaining the unfixed wing tip portion (see FIGS. **4**A, **5**A, **6**A) without rotation to provide an unfolded flight condition **132** (see FIGS. **4**A, **5**A, **6**A).

As will be appreciated by those of skill in the art, incorporating the swing wing tip system **80** (see FIGS. **3**A, **4**A, **5**A, **6**A) and the swing wing tip assembly **82** (see FIGS. **3**A, **4**A, **5**A, **6**A) into the wing **18** (see FIG. **1**) of an air vehicle **10** (see FIG. **1**), such as an aircraft **11** (see FIG. **1**), results in a number of substantial benefits. Disclosed embodiments of the swing wing tip system **80** (see FIGS. **3**A, **4**A, **5**A, **6**A), the swing wing tip assembly **82** (see FIGS. **3**A, **4**A, **5**A, **6**A), and method **200** (see FIG. **8**) provide a design that allows the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A) to rotate aft in an aft folded ground position **136** (see FIGS. **4**E, **5**F, **6**C) in order to facilitate a reduced wing span **21***a* (see FIG. **3**A) during ground movement of the air vehicle **10** (see FIG. **1**), such as at airport runways and taxiways and during airport gate parking. In addition, the design allows the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A) to rotate forward from the aft folded ground position **136** to the unfolded flight position **132** (see FIGS. **4**A, **5**A, **6**A) for high speed aerodynamic benefit. Further, in one embodiment, the design allows the unfixed wing tip portion **76** (see FIGS. **3**A, **4**A) to rotate forward from the unfolded flight position **132** (see FIGS. **4**A, **5**A, **6**A) to a forward folded flight position **134** (see FIG. **4**D) for low speed take-off and climb conditions.

Thus, disclosed embodiments of the swing wing tip system **80** (see FIGS. **3**A, **4**A, **5**A, **6**A), the swing wing tip assembly **82** (see FIGS. **3**A, **4**A, **5**A, **6**A), and method **200** (see FIG. **8**) provide a wing **18** (see FIG. **1**) that is optimized for both low speed and high speed positions. In addition, they provide a wing **18** (see FIG. **1**), such as in the form of swing wing **18***a*, having a wing tip **20**, such as in the form of swing wing tip **20***a* (see FIG. **3**A), with the capability to change the wingspan **21** (see FIG. **1**) of the air vehicle **10**, while allowing the air vehicle **10** (see FIG. **1**) to be more efficient in flight with a wingspan **21** (see FIG. **1**) that is longer or increased in length, yet still being able to stay within existing airport restrictions, i.e., 213 foot wingspan or less. For example, one embodiment of the swing wing tip system **80** (see FIG. **3**A) and swing wing tip assembly **82** (see FIG. **3**A) may provide a wingspan **21** (see FIG. **1**) that is lengthened or increased by an additional 8 (eight) feet or more to enhance take-off and climb performance when the unfixed wing tip portion **76** (see FIG. **3**A) of the wing **18** (see FIG. **1**) is rotated or folded forward at the take-off position, e.g., rotated about 30 (thirty) degrees forward.

Moreover, disclosed embodiments of the swing wing tip system **80** (see FIGS. **3**A, **4**A, **5**A, **6**A), the swing wing tip assembly **82** (see FIGS. **3**A, **4**A, **5**A, **6**A), and method **200** (see FIG. **8**) provide a wing **18** (see FIG. **1**), such as in the form of swing wing **18***a*, **18***b*, **18***c* (see FIG. **3**A), having a dual load path structure **83** (see FIG. **3**A) with dual wing skin plates **104** (see FIG. **3**A), dual rotation elements **86** (see FIG. **3**A), a dual rotation pin element **88** (see FIG. **3**A), and other suitable redundant structures. The dual load path structure **83** (see FIG. **3**A) provides fail-safe load paths **160** (see FIG. **3**A) for primary load carrying members, such as the wing **18** (see FIG. **1**) of the air vehicle **10** (see FIG. **1**). The dual load path structure **83** (see FIGS. **3**A, **4**B, **5**B, **6**A) provides two separate load bearing paths to carry a load in a fail-safe manner, one path carrying the load upon failure of the other, and thus may provide improved safety of the air vehicle **10** (see FIG. **1**).

In addition, positioning the dual rotation pin element **88** (see FIG. **4**B) between the dual wing skin plates **104** (see FIG. **4**B), i.e., dual devises, may provide replaceability of the unfixed wing tip portion **76** (see FIG. **4**B) in a manner similar to replaceability of known winglets while still providing substantial torsional stiffness of the rotation joint **84** (see FIG. **4**B). Thus, a minimum maintenance may be performed, as compared to winglet or wing configurations that allow no access or no maintenance.

In addition, disclosed embodiments of the swing wing tip system **80** (see FIGS. **3**A, **4**A, **5**A, **6**A), the swing wing tip assembly **82** (see FIGS. **3**A, **4**A, **5**A, **6**A), and method **200** (see FIG. **8**) provide a wing **18** (see FIG. **1**) having shear load paths **72** that are improved and having the capability to direct about a 200 (two hundred) degree shear load transfer from the unfixed wing tip portion **76** (see FIG. **4**B) to the fixed wing portion **78** (see FIG. **4**B) at the rotation joint **84** (see FIG. **4**B).

Moreover, disclosed embodiments of the swing wing tip system **80** (see FIGS. **3**A, **4**A, **5**A, **6**A), the swing wing tip assembly **82** (see FIGS. **3**A, **4**A, **5**A, **6**A), and method **200** (see FIG. **8**) provide a wing **18** (see FIG. **1**) having a moving panel **120** (see FIG. **3**A) that may be rotated and tucked within the wing **18** during rotation of the unfixed wing tip portion **76** (see FIG. **3**A). The moving panel design thus eliminates the use of known slaved doors or folding panels on the wing. This, in turn, may improve operation of the swing wing tip system **80** (see FIGS. **3**A, **4**A, **5**A, **6**A), the swing wing tip assembly **82** (see FIGS. **3**A, **4**A, **5**A, **6**A) during flight.

Many modifications and other embodiments of the disclosure will come to mind to one skilled in the art to which this disclosure pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. The embodiments described herein are meant to be illustrative and are not intended to be limiting or exhaustive. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

What is claimed is:

**1**. A swing wing tip system for an air vehicle, the system comprising:

a swing wing tip assembly comprising:

an unfixed wing tip portion movably connected to a fixed wing portion of a wing of an air vehicle;

a dual load path structure providing two separate load bearing paths comprising dual wing skins and a rotation joint to carry load in a fail-safe manner, and the dual load path structure configured to transfer load from the unfixed wing tip portion to the fixed wing portion, the dual load path structure comprising:

dual wing skin plates comprising an upper wing skin with a separate plate portion attached to the upper wing skin and comprising a lower wing skin with another separate plate portion attached to the lower wing skin, the separate plate portions being flush with the respective upper wing skin and the lower wing skin; and

the rotation joint coupled between the dual wing skins and configured to rotationally couple the unfixed wing tip portion to the fixed wing portion, the dual wing skins positioned across both sides of the rotation joint, the rotation joint comprising:

a dual rotation pin element having a center rotation axis; and,

dual rotation elements configured to rotate about the center rotation axis;

an actuator assembly operatively coupled to the rotation joint to actuate the rotation joint enabling rotation of the unfixed wing tip portion with respect to the fixed wing portion about the center rotation axis at a selected operation condition; and,

a controller system operatively coupled to the actuator assembly to control actuation of the rotation joint and rotation of the unfixed wing tip portion.

**2**. The system of claim **1** further comprising a navigation element positioned near a hinge line between the fixed wing portion and the unfixed wing tip portion and operable to be exposed and activated in response to rotation of the unfixed wing tip portion.

3. The system of claim 1 wherein the swing wing tip assembly further comprises a moving panel positioned near a trailing edge of the unfixed wing tip portion and configured to move before the unfixed wing tip portion is rotated.

4. The system of claim 1 wherein the dual load path structure further comprises dual channel segments coupled between the dual wing skins.

5. The system of claim 1 wherein each plate portion comprises a titanium plate portion.

6. The system of claim 1 wherein the dual rotation pin element comprises one of: a disc pin, a pivot pin, and a plate pin.

7. The system of claim 1 wherein the dual rotation elements comprise one of: lug elements, rotation fitting elements, and rotation plate elements.

8. The system of claim 1 wherein the actuator assembly comprises one of: a rotary electric actuator assembly, a linear hydraulic actuator assembly, and a ball screw actuator assembly.

9. The system of claim 1 wherein the actuator assembly comprises an actuator element and a locking element, the locking element configured to lock the unfixed wing tip portion in a rotation position relative to the fixed wing portion when the actuator element actuates the rotation joint.

10. The system of claim 1 wherein the selected operation condition provides a position of the unfixed wing tip portion comprising one of: an unfolded flight position, an aft folded ground position, and a forward folded flight position.

11. An aircraft having fail-safe load paths for one or more wings, the aircraft comprising:

at least one fuselage;

one or more wings having a swing wing tip assembly, the swing wing tip assembly comprising:

an unfixed wing tip portion movably connected to a fixed wing portion of the one or more wings;

a dual load path structure providing fail-safe load paths comprising dual wing skins and a rotation joint to carry load in a fail-safe manner for the one or more wings and dual load path structure configured to transfer load from the unfixed wing tip portion to the fixed wing portion, the dual load path structure comprising:

dual wing skin plates comprising an upper wing skin with a separate titanium plate portion attached to the upper wing skin and a lower wing skin with another separate titanium plate portion attached to the lower wing skin, the separate titanium plate portions being flush with the respective upper wing skin and the lower wing skin; and

the rotation joint coupled between the dual wing skins and configured to rotationally couple the unfixed wing tip portion to the fixed wing portion, the dual wing skins positioned across both sides of the rotation joint, the rotation joint comprising:

a dual rotation pin element having a center rotation axis; and,

dual rotation elements configured to rotate about the center rotation axis; and,

dual channel segments coupled between the dual wing skins;

an actuator assembly operatively coupled to the rotation joint to actuate the rotation joint enabling rotation of the unfixed wing tip portion with respect to the fixed wing portion about the center rotation axis at a selected operation condition;

a controller system operatively coupled to the actuator assembly to control actuation of the rotation joint and rotation of the unfixed wing tip portion; and,

a navigation element positioned near a hinge line between the fixed wing portion and the unfixed wing tip portion and operable to be exposed and activated in response to rotation of the unfixed wing tip portion.

12. The aircraft of claim 11 wherein the aircraft has a wingspan configured to reduce in length to provide a reduced wingspan to allow ground operation of the aircraft at an airport that prohibits ground operation of aircraft with an expanded wingspan.

13. The aircraft of claim 11 wherein the selected operation condition provides a position of the unfixed wing tip portion comprising one of: an unfolded flight position, an aft folded ground position, and a forward folded flight position.

14. The aircraft of claim 11 wherein the swing wing tip assembly further comprises a moving panel positioned near a trailing edge of the unfixed wing tip portion and configured to move before the unfixed wing tip portion is rotated.

15. A method for providing fail-safe load paths for a wing of an air vehicle, the method comprising the steps of:

operatively coupling a swing wing tip assembly to a wing of an air vehicle, the swing wing tip assembly comprising:

an unfixed wing tip portion movably connected to a fixed wing portion of the wing; and,

a dual load path structure providing two separate load bearing paths comprising dual wing skins and a rotation joint to carry load in a fail-safe manner, and the dual load path structure comprising:

dual wing skin plates comprising an upper wing skin with a separate plate portion attached to the upper wing skin and comprising a lower wing skin with another separate plate portion attached to the lower wing skin, the separate plate portions being flush with the respective upper wing skin and the lower wing skin; and,

a rotation joint coupled between the dual wing skins, the dual wing skins positioned across both sides of the rotation joint, the rotation joint comprising a dual rotation pin element having a center rotation axis and dual rotation elements configured to rotate about the center rotation axis;

operatively coupling an actuator assembly to the rotation joint;

operatively coupling a controller system to the actuator assembly to control the actuator assembly to actuate the rotation joint; and,

transferring load from the unfixed wing tip portion to the fixed wing portion via the dual load path structure to provide fail-safe load paths for the wing.

16. The method of claim 15 further comprising the step of rotating the unfixed wing tip portion with respect to the fixed wing portion about the center rotation axis at a selected operation condition.

17. The method of claim 16 wherein the step of rotating the unfixed wing tip portion at the selected operation condition further comprises rotating the unfixed wing tip portion to provide an aft folded ground position.

18. The method of claim 16 wherein the step of rotating the unfixed wing tip portion at the selected operation condition further comprises rotating the unfixed wing tip portion to provide a forward folded flight position.

19. The method of claim 16 further comprising operatively coupling a navigation element near a hinge line between the

fixed wing portion and the unfixed wing tip portion to be exposed and activated in response to rotation of the unfixed wing tip portion.

**20**. The method of claim **16** further comprising the step of moving a moving panel positioned near a trailing edge of the unfixed wing tip portion before rotating the unfixed wing tip portion.

**21**. The method of claim **15** further comprising the step of maintaining the unfixed wing tip portion without rotation to provide an unfolded flight position.

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